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THE PENNSYLVANIA ASSOCIATIONS OF JOSEPH PRIESTLEY.

BY

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PART II.

NORTHUMBERLAND ACADEMY.

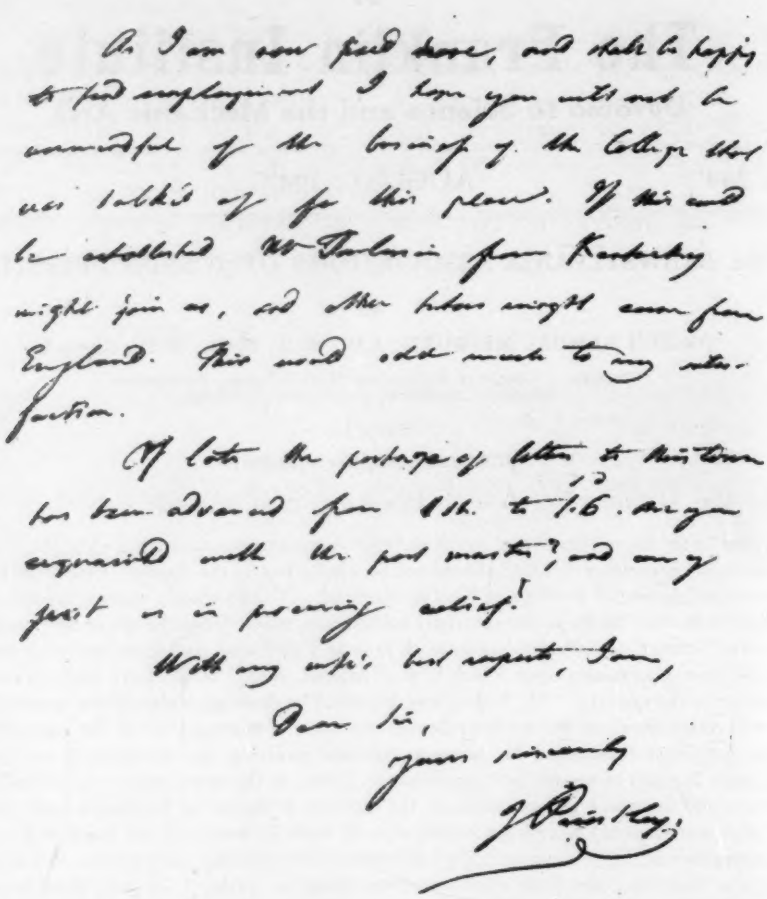
In the *Memoirs* [3] of Joseph Priestley, it is related:

"Soon after his settlement at Northumberland, many persons, with a view that his qualifications as an instructor of youth should not be wholly lost to the country, concurred in a plan for the establishment of a college at Northumberland. To this scheme several subscribed from this motive alone. Many of the principal landowners, partly from the above and partly from motives of interest, contributed largely both in money and land, and there was a fair prospect, from the liberal principles upon which it was founded, that it would have been of very great advantage to the country. My father was requested to draw up a plan of the course of study he would recommend, as well as the rules for the internal management of the institution, and he was appointed President. He however declined receiving any emolument, and proposed giving such lectures as he was best qualified for, *gratis;* in the same manner as he had done at Hackney, and he meant to have given to the institution the use of his library and apparatus, until the students could have been furnished with them by means of the funds of the college. In consequence of the unexpected failure of some of the principal contributors, the scheme fell through at that time, and little more was done during my father's life time than to raise the shell of a convenient building."

On January 4, 1795, Priestley [15] wrote from Northumberland to John Vaughan: "I hope you will not be unmindful of the business of the College that we talked of for this place. If this can be established Mr. Toulmin from Kentucky might join us, and other tutors might come from England. This would add much to my satisfaction." The reference apparently is to Harry Toulmin who was president of Transylvania University from February, 1794 to April, 1796. The illustration shows a portion of this letter, and is used by courtesy of the American Philosophical Society from a paper in its *Library Bulletin.*[67]

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

In another letter to Vaughan, dated Northumberland, August 11, 1795, Priestley [15] wrote: "My son will talk to you about the visit I propose to pay you, and the *College* about which I suppose nothing can be done till the buildings are erected the next year."



The scientific correspondence of Joseph Priestley, as privately printed by Bolton,[55] consists on ninety-seven letters written by Priestley. In four letters, written at Northumberland, mention is made of the "college" or "academy." On November 3, 1794, Priestley wrote to Benjamin Rush at Philadelphia "hoping we shall succeed in establishing a College in this place." On November 11, 1794, he again wrote to Rush stating that he is "waiting for the opportunity of being of use to the College which I hope will be established here." In still another letter to Rush on May 22, 1795, Priestley spoke: "We are much obliged to you for the pains you have taken about our *Academy*. As the sit-

uation is not unfavorable, I hope it will succeed." On October 27, 1795, Priestley wrote to William Withering of Birmingham, England: "Soon, however, I expect to be employed in the instruction of youth, as a *college* is to be established in this place, and I am appointed the principal. The next spring we begin to build; but our funds will be small. I wish we had a proper person for teaching *Natural History*, including Botany. Almost everything else I can, *pro tempore*, in some measure, teach myself. When our common hall is erected, I shall also make use of it as a chapel, for such is the bigotry of the people in this part of the country, that tho' in every other respect my reception has been very flattering, their pulpits are all shut to me" In these letters Priestley also speaks of the professorship of chemistry in the University of Pennsylvania, and his reasons for declining the appointment.

The General Assembly was petitioned to aid the Northumberland Academy. The report of the Committee, to which this petition was referred, was published in the *Aurora* [32] in April, 1803. The recommendations made in this report were embodied, with minor changes, in a law enacted the following January. In the report, as in the law, mention is made of the library at the disposal of Priestley whose name is erroneously given as Priestly.

An Act of Assembly approved January 20, 1804, is entitled "An Act in aid of the Northumberland Academy in the town and county of Northumberland." [33] Since Priestley is mentioned in both the preamble and one section of the Act, though his name is misspelt "Priestly," the text of the Act is here given:

"Whereas, it is represented to the legislature, that the trustees of Northumberland Academy have erected a building for that institution, but, owing to the failure of sundry principal subscribers, they are unable to finish the same, or discharge the debts already contracted; and the said trustees have prayed for legislative aid in the premises: And whereas, it is represented, that Doctor Joseph Priestly has the disposal of a valuable library of scarce and well-assorted books, in various branches of literature and science, which he is desirous and has the power of procuring as a gift to Northumberland Academy, provided that institution is likely to receive substantial aid from the state: And whereas, it has ever been the enlightened policy of Pennsylvania, to encourage and cherish seminaries of useful learning: Therefore,

Section 1. *Be it enacted by the Senate and House of Representatives of the Commonwealth of Pennsylvania, in General Assembly met, and it is hereby enacted by the authority of the same,* That two thousand dollars of the arrearages of state taxes now due from the county of Northumberland, be, and are hereby granted to the trustees of the Northumberland Academy, to and for the use of that institution; to be paid by the treasurer of said county, out of the arrearages of state taxes that hereafter may come into his hands; which sum so paid shall be allowed said treasurer on the settlement of his accounts.

Sect. 2. *And be it further enacted by the authority aforesaid,* That whenever Doctor Joseph Priestly, or any person by him for that purpose appointed, shall certify to the Governor of this commonwealth, that he hath a library of not less than two thousand volumes, of such as may be selected and approved by the trustees of the said institution, or a majority of them, ready to appropriate as a donation to the Northumberland Academy, the Governor shall be authorized to appoint two persons, disinterested, who shall not reside within the county of Northumberland, to value the same; which valuation the Governor shall report to the legislature at their

next session, together with a catalogue of said books, recommending an appropriation or donation of money, to and for the use of said institution, equal to the aforesaid valuation: *Provided*, That such valuation shall not amount to more than three thousand dollars."

The Act was approved by Thomas M'Kean, Governor of the Commonwealth; he held that office from December 17, 1799 to December 20, 1808, and had been Chief Justice of the Supreme Court of Pennsylvania from July 28, 1777 to December 16, 1799.

Priestley died at Northumberland on February 6, 1804. In his monograph "Priestleyana," Edgar Fahs Smith [24] relates how the library of Priestley was sold by Thomas Dobson of Philadelphia in 1816.

"An Act for the relief of the trustees of the Northumberland Academy" [34] was approved March 28, 1808. From this Act, it is learned that the trustees of the Academy had received only four hundred and thirty dollars of the absolute grant of two thousand dollars and none of the conditional grant of three thousand dollars "owing to the impossibility of complying with the conditions thereto annexed." Meanwhile they had borrowed money to enable them to finish one-half of their building. It was therefore enacted: "That the treasurer of Northumberland county shall pay out of the arrears of loan office money, which may come into his hands, the sum of two thousand dollars, to the trustees of Northumberland academy for the use thereof." The following proviso was attached. "*Provided*, That the said trustees do release under their hands and seals, all right, title, claim and demand which they either now have or hereafter may have, to three thousand dollars conditionally granted to them for the use of said academy, by an act of the general assembly, passed January twentieth, one thousand eight hundred and four, and that the said trustees do also release under their hands and seals, all right and title which they have to demand and receive from the treasurer of Northumberland county, any further arrearages of state taxes under the aforesaid act, which releases shall be duly filed in the office of the secretary of the commonwealth."

In the records of Northumberland County, the Collector's Account Book for 1785–97 contains accounts later than the year 1797. The account of the Trustees of the Northumberland Academy is:

Dr. The Trustees of North'd. Academy in account with the State of Pennsylvania, Cr.

1805 To cash paid John Boyd, Treas. for said Academy		$ 199.04
1806 To cash paid John Boyd, Treas. per S. Snyder		148.33
1807 To cash paid John Boyd, Treas. advanced out of county monies		400.00
1808 To cash paid John Boyd, Treas. out of Loan Office per Snyder		1200.00
	Bal.	52.63
		$2000.00

By a grant of the Legislature as p. act. of the 20th Jan. 1804 to be paid out of State Taxes collected in Northumberland County. A second act passed 28th March 1808. Residue to be paid out of Loan Office money.

By two indentures, made March 9, 1815, and recorded May 12, 1859, between John Smith Haines [35] of Northumberland and the Trustees of the Northumberland College, Haines "for and in consideration of his Father Josiah Haines having promised the aftermentioned piece of ground to the trustees as a site for the College and also for one dollar" conveyed to the trustees and their successors a lot of ground in Point Township on West Way adjacent to the town of Northumberland "being the same on which the Northumberland College is built containing in the whole five acres be the same more or less." The grant was made "to and for the only proper use and behoof of the corporation of which the said party of the second part are trustees forever."

Mulhern [36] states that the Northumberland Academy in 1827 charged five dollars per quarter in the classical department and three dollars per quarter in the English department, and that its principal then undertook to board in his family students from a distance, and cites a published notice as the authority for these statements. According to this notice [56] which ran for six consecutive weeks, the Rev. Robert Elliot, LL.D., a former chaplain of the United States Senate, had recently been appointed Principal, and the curriculum included Greek, Latin, Mathematics, Logic, "Rhetorick," Geography, English Grammar and Composition, and the minor branches of an English education, "&c." The notice is signed "By order of the Board, James Hepburn, Sec'y.," and dated September 25, 1827. The annals of Congress [60] record that Elliot was elected chaplain by the House of Representatives at the Second Session of the Ninth Congress on December 4, 1806, and by the Senate at the Second Session of the Tenth Congress on November 10, 1808.

By deed poll, acknowledged before the Court of Common Pleas of Northumberland County in open court on August 24, 1831, Peter Lazarus, High Sheriff of Northumberland County, granted to John Cowden the lot of ground in the Borough of Northumberland on Westway containing five acres more or less on which is erected a two story double house, heretofore used as an Academy, seized and taken in execution as the property of the Trustees of the Northumberland Academy by virtue of a writ of fieri facias issued out of the said Court at the suit of John Miller, assignee of John Vaughan, and sold on August 17, 1831 by virtue of a writ of venditioni exponas issued out of the said Court. The consideration was fifteen hundred dollars. This suit had been begun in the August Term, 1824, as an amicable action in debt for four hundred and nine dollars and fifty seven cents. Judgment was confessed for that sum with costs of suit. In this suit, a writ of scire facias was served in August Term, 1830 on John Boyd, Treasurer of the Northumberland Academy, and on Israel Pleasants and Judge Chapman, Trustees. In November Term, 1830, an alias scire facias was served on

John Boyd, Treasurer, and on Israel Pleasants and Joseph R. Priestley, Trustees.[37]

In August Term, 1824, five other judgments were entered against the Trustees of the Northumberland Academy. The plaintiffs were Henry Clymer,[61] William Lloyd,[62] John Cowden,[63] Samuel Jackson,[64] and John Boyd.[65] Clymer obtained judgment for sixteen dollars plus four dollars and sixty cents costs. The suit of Boyd was an amicable action in debt, for the balance of his account as treasurer of the corporation; judgment was confessed for one hundred and ten dollars and ninety five cents with costs of suit. Each of these judgments was revived in the August Term, 1828 by writs of scire facias. In the suit by Clymer and in that by Boyd, the writ was served on Joseph R. Priestley. Apparently no further action was taken in any of these five suits.

The *Report of the Superintendent of Common Schools of Pennsylvania* for the year ending June 2, 1862 contains statistics on county academies.[38] According to this report, the academy at Northumberland in Northumberland County had been granted state appropriations amounting to four thousand dollars between the years 1804 and 1808, had a two story brick building and one-quarter acre of ground. No data are given for value, funds, and pupils. Under "Present condition" is the statement "Not in operation for years."

An Act of Assembly (No. 301) [39] approved April 5, 1862 provided in its first section: "That any two of the surviving members of the board of trustees of the Northumberland academy, who may be residing in the borough of Northumberland, Pennsylvania, at the date of the passage of this act, be and they are hereby authorized and empowered to assign, transfer, set over and convey, all the funds, moneys, bonds, claims, demands, lots, and property, real, personal and mixed, of the Northumberland academy, to the board of school directors of the said borough of Northumberland, their successors and assigns, for the use of the school district of the borough of Northumberland aforesaid."

A second section of this Act authorized the directors of said school district to dispose of all the property of the said academy acquired by them in pursuance of the first section, and to apply the proceeds thereof "towards the construction of such school houses as in their judgment may be required for the use of said district."

By indenture,[40] made May 17, 1864, and recorded March 26. 1946, "between William Forsyth and John Taggart surviving members of the board of Trustees of the Northumberland academy as aforesaid, residing, in the Borough of Northumberland" and "M. I. D. Withington, C. B. Renninger, D. G. Voris, John U. Hopewell, George Everand and C. F. Little School directors of the Borough of Northumberland," the surviving trustees, for and in consideration of the sum of One Dollar, granted to the school directors lot number 106 on the plan of said borough located on West Way. The indenture begins with a statement of

the authority, granted by the Act of Assembly, to convey the property of the trustees to the board of school directors. It bears the signatures and individual seals of "Wm. Forsyth" and "Jn. Taggart," but no corporate seal. The receipt for the consideration bears the signature "Jn. Taggart." The acknowledgment states that William Forsyth and John Taggart personally appeared before D. B. McGregor, J. P., Justice of the Peace, on May 17, 1864, acknowledged the indenture to be their act and deed, and desired the same might be recorded as such.

A short account of the Northumberland Academy is contained in a paper by John F. Wolfinger [41] on "Oldest Schools in Northumberland County." Wolfinger describes it as an ornamental, two-story brick building on the corner of Westway and Second Street, erected in 1803. Its first principal was Rev. William Christie; his successors were Rev. Isaac Grier, Robert C. Grier, Rev. Robert F. N. Smith, and Rev. Elijah D. Plumb.

Ball's "History of Northumberland County" [42] quotes Wolfinger's paper.

Wickersham,[43] in his "History of Education in Pennsylvania," gives additional information concerning this Academy. "The school was reasonably prosperous in its earlier years, but subsequently fell into decay, and the greater part of the property was sold to pay debts."

Both Rupp [57] and Lesher [58] mention this Academy.

In his brochure, "Northumberland: The Story of An Old Town: 1829–1929", C. Warren Gutelius [29] devoted a section to "the old college." In another section, he described an episode of the Civil War in 1863 and mentioned that "a car of ordnance stood near the old college." Hence it appears that the academy building was still standing in that year.

William Christie had been a collaborator in the completion of Priestley's "Memoirs." [3] Mulhern [36] cites an announcement of the Academy in the Sunbury *Times*. The announcement [59] is signed: "By order of the Board, John Boyd, Chairman." Rev. Isaac Grier had been appointed Principal; boarding and lodging were available to a few scholars in his family. The Academy had opened on May 10, 1813 for instruction in Latin, Greek, Mathematics, Geography, and English Grammar. However Grier was dead when the indentures of 1815 were made, for they mention an adjoining "lot or piece of ground belonging to the Estate of the Reverend Isaac Grier deceased." [35]

The library of the Presbyterian Historical Society in Philadelphia contains a manuscript copy of the obituary notice of the Rev. Isaac Grier as recorded in the *Obituary Book of Northumberland Presbytery*. He was born in Franklin County, Pennsylvania in 1763, graduated from Dickinson College in 1788, was licensed to preach in 1791, "appointed to missionate" in the Susquehanna valley in 1792, ordained in 1794, and called by the united congregations of Sunbury and Northumberland in

1806. "In addition to the pastoral care of these churches, and the supplying the church at Shamokin once a month, he undertook the charge of the Academy or College as it was then called." He was one of the five members who constituted the Presbytery of Northumberland at its organization in October, 1811. He died on August 23, 1814. The Academy then was in a "flourishing state."

Robert C. Grier, who was the son of Rev. Isaac Grier, and succeeded his father as principal of the Academy, became a justice of the Supreme Court of the United States. In the list of justices of that Court, published in the "Senate Manual," Robert C. Grier [44] is number 27 in the list of Associate Justices; he was appointed from Pennsylvania, and served from August 4, 1846 to January 31, 1870.

Robert F. N. Smith [66] was a Presbyterian clergyman, and minister of the congregations at Northumberland and Sunbury in the Presbytery of Northumberland in 1819. He died in Mississippi about 1825.

Rev. Elijah G. Plumb is mentioned in the records of the Protestant Episcopal Church in the State of Pennsylvania.[45] In his address to the diocesan convention in May, 1819, Bishop White reported that Plumb had entered on missionary duty in Northumberland. In his address to that convention in May, 1821, Bishop White recorded the decease of Plumb of Northumberland. The *Journal* of the convention of 1820 states that "Plum" was one of the clergy entitled to a seat, but was absent. He is listed as "Elijah G. Plum. Principal of an academy and performing Missionary services at Northumberland."

Under date of February 19, 1945, Walter B. Henninger, Supervising Principal of the Northumberland Public Schools, stated "One or two of the oldest inhabitants of the town have a dim recollection of the academy building."

In the official records of Northumberland County,[46] the terms college and academy are applied as late as the year 1871 to describe the property covered by the indentures of 1815. A sheriff's deed acknowledged in 1844 shows that the academy building was then used for a mill and dwelling house. In proceedings in the Orphans' Court (Estate of Charles H. Kay, Deceased) in 1855 this real estate is described as "unproductive and rapidly becoming delapidated and decayed." Incidentally, the title to this property was held, from 1856 until his death in 1863, by Joseph R. Priestley, the grandson of Joseph Priestley, and remained in his estate until 1871.

Title to the "college" property of 1815 is now vested partly in The Pennsylvania Railroad Company and partly in one its subsidiaries, Northern Central Railway Company.

Title to at least a part of lot number 106 is now vested in The Pennsylvania Railroad Company.

The weight of the evidence is that this educational institution at Northumberland was an academy. The only specific use of the word

"college" is in the two deeds of March 9, 1815. In the three cited Acts of Assembly (1804, 1808, and 1862), in the sheriff's deed of August 17, 1831, in the deed of May 17, 1864, and in the notices published by its trustees in 1813 and 1827, the word "academy" is used. The State Historian of Pennsylvania has informed the author that, as a result of a thorough check of the records of the office of the Secretary of the Commonwealth, "there is nothing to indicate the existence of a college at Northumberland." In his "Digest," Beitel [47] makes no mention of Northumberland under either colleges or universities; under academies, he cites the Acts of Assembly of 1808 and 1862 concerning the Northumberland Academy.

The weight of the evidence is that the institution at Northumberland was not incorporated. Neither of the Acts of Assembly cited by Beitel nor the earlier Act of Assembly of 1804 created a corporation. The office of the Secretary of the Commonwealth (the Department of State) of Pennsylvania has been unable to find any record of a legislative, Supreme Court, or other charter issued to either the Northumberland Academy or the Trustees of Northumberland Academy. The records of the Supreme Court of Pennsylvania for the Middle District at Harrisburg between 1790 and 1815 make no reference to Northumberland Academy, Northumberland College, or the Trustees of either institution. The records for its Eastern District at Philadelphia are silent on the subject. These facts tend to exclude the possibility of an uncompleted Supreme Court charter. There is no record of the incorporation of either Northumberland College or Northumberland Academy by the Court of Common Pleas of Northumberland County. The present records of the Northumberland Public Schools do not go back to the transfer of the academy property (lot 106) to the Board of School Directors in 1864. There is nothing of record to the Northumberland Academy or College for this lot; title evidently was taken by the trustees of the academy as individuals and not as an incorporated body. Lastly, the official documents reveal that the Northumberland Academy was not incorporated. The Act of Assembly of 1808 required its trustees to execute two releases for two prior grants, each release "under their hands and seals," not under a corporate seal. The deed, executed by the surviving trustees in 1864 under the Act of Assembly of 1862, bears the individual signatures and seals of two surviving trustees, but no corporate seal.

THE OXYGEN CENTENNIAL AND ITS AFTERMATH.

In April, 1874, H. Carrington Bolton [48] of the School of Mines of Columbia College, now Columbia University in the City of New York, proposed, in the *American Chemist*, that the centennial of the discovery of oxygen by Joseph Priestley be celebrated on August 1, 1874. The celebration was held, and an account thereof published in the same

journal [49] between August and December, 1874. At the suggestion of Rachel L. Bodley, professor of chemistry in the Woman's Medical College of Pennsylvania (1866–1888) [50], the celebration was at Northumberland, on July 31 and August 1, 1874; and part of the ceremonies were at the grave of Priestley. During the meeting, Persifor Frazer, Jr., who was assistant professor of natural philosophy and chemistry (1871–1872) and professor of chemistry (1872–1874) in the University of Pennsylvania, "proposed the formation of a chemical society."

Frazer's proposal bore fruit when the American Chemical Society was organized in New York City on April 6, 1876, and incorporated, first under the laws of the State of New York [51] by a Certificate, approved by a Justice of its Supreme Court, and filed at Albany in the Office of the Secretary of State on November 19, 1877, and, later, by a special Act of Congress [52] approved August 25, 1937.

Reminiscences of this meeting of 1874 were published by Goldschmidt.[53]

The semi-centennial of the founding of the American Chemical Society [18] was celebrated in 1926 at its general meeting in Philadelphia. However, the first session of that meetiug was held on September 5, 1926 in Northumberland at the grave and the home of Joseph Priestley. On that occasion, the museum on the lawn of his home was dedicated.

Meanwhile, in 1922, the American Chemical Society [54] had presented to the U. S. National Museum a portrait of Priestley, and had founded its Priestley Medal for distinguished services to chemistry. At least twenty Philadelphians were contributors to the fund.

ACKNOWLEDGMENTS.

Much of the data on Priestley's home was furnished by Suzanne Kirby (Mrs. George H.) Neff of "Priestley," Northumberland. Richard Henry Klein, Esq., of the Sunbury Bar, has been most gracious and generous in searching the official records of Northumberland County for items concerning the Northumberland Academy. J. V. B. Duer and Ralph J. Leety of the general offices of The Pennsylvania Railroad Company have made available the records of title to the real estate formerly the property of that Academy but now owned by the Railroad. Phelps Soule, former Secretary, and Ronald J. McCarthy, Assistant Secretary, of the University of Pennsylvania permitted the author to consult the original minutes of the trustees of that corporation. The quest for information from the original sources has been aided by the Honorable Israel Stiefel, the Honorable Anthony J. DiSilvestro and the late Honorable Franklin Spencer Edmonds, members of the Senate of Pennsylvania; Helen W. Speck, Deputy Prothonotary of the Supreme Court at Harrisburg; Robert L. Davis, Burgess of Northumberland; Walter B. Henninger, Supervising Principal of its Public Schools; Marian E. Mauser of the Bloomsburg Public Library; Dr. Ernest A. Vuilleumier,

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Europe's Largest Suspension Bridge to Span Severn. (*Civil Engineering*, Vol. 17, No. 1.)—Traffic from England to South Wales will soon cross the lower reaches of the River Severn on a 3000-ft. main-span suspension bridge—Europe's largest—relieving congested traffic conditions farther north and permitting South Wales, a coal mining center, to develop industrially. The proposed bridge will replace a ferry—whose predecessors date back 2000 years—linking Beachley, England, with Aust in Wales.

The new bridge is to be a four-lane structure desinged to carry 4000 vehicles per hour. End spans of 1000 ft. give the bridge an overall length of 5000 ft. between anchorages. Vertical clearance provided for shipping will range from 110 ft. above high tide, near the 450-ft.-high steel towers, to a maximum of 120 ft. at the center of the main span.

Included in the project are plans for the construction of approach roads on either side of the bridge, and a bridge over the River Wye. The entire project, including approach roads and bridges which total about 8 miles in length, will cost about 30,000,000. The new Wye Bridge is to have six spans of 150 ft., two of 175 ft. and a central span of 200 ft.

R. H. OPPERMANN.

Test Thermal Energy for Home-Heating Use. (*Coal Age*, Vol. 52, No. 1.)—A practical test of the application of the earth's thermal energy to domestic heating plants is planned for the coming winter by the Chattanooga Electric Power Board. Five homes, according to an announcement recently, will have installations of a reverse-cycle heat pump operating on water secured from 200-ft. wells. The electrically operated equipment offers a possibility of equalizing power demand throughout the entire year, the power board believes. In fact, a radical change in present electricity and fuel consumption by both utilities and the public is possible if the unit proves economically feasible.

Water secured at the 200-ft. level is expected to maintain a temperature of 58° F. and will be pumped to a refrigerating unit in each house. Heat given off in the refrigeration of the water will be absorbed by the refrigerant gas, the compression of which will generate still more heat. The heat is transmitted to the air circulating through the house by coils. In summer, the unit can be used equally well to cool the house. While the process is not new, this is thought to be the first test of its commercial possibilities in that part of the country. If these tests are successful, it may be possible to use water from the Tennessee River to heat downtown Chattanooga instead of drilling costly wells, according to S. R. Finley, Superintendent of the power board.

In addition to equalizing demand, heating by this method is expected to take only one-fourth the electricity used by ordinary resistance-type house heaters and rising power demands have been another factor in the power board's decision to test the unit.

R. H. OPPERMANN.

SOME ASPECTS AND RECENT RESULTS OF ELECTROMAGNETIC EFFECTS OF THUNDERSTORMS.

BY

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PART I.

INTRODUCTION.

The Institute of High Tension Research of the University of Uppsala has as one of its main purposes to investigate the electrical character and effects of thunderstorms. This general aim of the Institute became already dictated by the conditions of a donation at its time given to the University by two donators.[1] They forwarded the general claim that the effective way to avoid the damages as caused by lightning discharges should be to develop extensive researches of the electrical conditions related to thunderstorms. During the years 1932–1934 an institute mainly bound by the above mentioned conditions was established in part by the support of the endowment. A considerable contribution was also given by the Swedish State. After a final judgment of the Swedish Parliament it followed as a matter of course that the researches of the new institute had to be developed after a comparatively broad scheme. Hence it became necessary to deal with so widely different subjects as lightning protective rod systems, lightning surges and arresters on transmission lines, discharges in the vicinity of the lightning channel, the effects of discharges at greater distances from the source of disturbance—the atmospherics.

Results of more general interest obtained at the Institute during the period before the second great world war have been published in this JOURNAL. The war conditions prevented us from continuing a publication. In the mean time we have been forced to give forth our results in Swedish publications (1, 2). Hence in the interests of continuity it may be of a certain value to publish a comprehensive article concerning the electromagnetic properties and effects of lightning discharges obtained at the Institute mainly during the war time and up to date.

We have found it convenient to arrange the results in the following parts: (1) Variations of the electric and the magnetic fields as caused by lightning discharges, (2) Current variation in lightning discharges, (3)

[1] A donation was given in 1918 to the University of Uppsala by the Swedish engineer B. John F. Andersson and Mrs. Svea Andersson. The conditions of the donation were that a professorship of electrophysics with special consideration to electrical atmospherical discharges should be instituted at the University. At the disposal of the professor should be erected a special laboratory.

The oscillographic investigation of a direct igniting and killing lightning stroke.

THE VARIATION OF THE ELECTRIC FIELD AS CAUSED BY LIGHTNING DISCHARGES.

THE OBSERVATION METHODS.

The method of observing the variation of the electric field as caused by lightning discharges is well known and has been described in detail earlier on (3). An open antenna circuit with an attenuation resistance connected to earth of such a value that the proper oscillations of the circuit are eliminated is used. The voltage variations as produced by the lightning discharges are recorded above a fitted part of the resistance by a cathode ray oscillograph. At small distances of the lightning paths, e.g., of the order of up to some tenths of kilometers, it will often be possible to record the variations by a direct connection with the deviation system of the oscillograph. A condition must be, that the deviation system of the plates is sensitive enough. At greater distances it is necessary to use an aperiodic amplifier of such a construction that all disturbances are eliminated of the incoming voltage variation forms.

Two different methods are possible, when we have to record the field force variation E. If a comparatively small resistance is used in the antenna circuit the variation of E with time or the dE/dt curves will be obtained. In order to find the E variation it is obviously necessary to integrate the dE/dt curves. The procedure is not a very convenient one but sometimes it will be necessary to apply the method especially when the antenna circuit is exposed in local fields carrying disturbances, e.g., from high tension transmission lines. The circuit has in the following records, if not anything else is mentioned, been adapted to give E curves. With regard to the details of calculation we refer to the paper (1).

FIELD VARIATIONS IN ADJACENT REGIONS OF LIGHTNING PATHS.

The transformation of the electric field as caused by lightning discharges with distance has first thoroughly been discussed by Lejay (4). Calculations of typical current variation forms have been carried out by the author (5). If the calculation is limited to a vertical lightning channel of the length h, the horizontal distance $r \gg h$, the current $I = \frac{dQ}{dt}$, the relation with distance of the electric force E_r will be:

$$E_r = \frac{2h}{r}\left(\frac{c^2}{r^2}Q + \frac{c}{r}\frac{dQ}{dt} + \frac{d^2Q}{dt^2}\right). \qquad (1)$$

Calculations from known variation curves of I resulted in rather complicated E_r curves as soon as the distances surpassed 5 km. Up to these distances from the lightning channel the first or the electrostatic term is always prevailing. In later on improved measurements we have ob-

served that the variation forms of the I curves were more complicated than was supposed to be valid when starting earlier calculations. Thus if we after our latest experience should try to find the variation form from the curves obtained at an observation point it will only lead to very complicated results, of which the real value will be a more formal one. Only systematic and simultaneous records at different distances of the variation forms of well defined lightning discharges will be able to give full information of the transition of the E field with the distance.

It is a well-known fact that the E variation from a flash at a distance of several hundred kilometers is characterized by slow-moving typical aperiodic or quasiperiodic variation forms. These types are not the real cause of the characteristic noise periods that are heard in radio receiving sets during thunderstorm periods. It must be some kind of rapid variation forms of the electric field that produce the noise effects. Every day many millions of radio listeners are confronted with the disturbances that are audible in the loud speakers. Only this fact should be quite a sufficient reason of devoting all efforts to find the disturbance sources. From a short listening period in a radio receiver with regard to the noise produced from a thunderstorm center will follow typical differences of both the noise character and its time duration. The conclusion will be that the lightning discharges and doubtless also intermediate discharge stages within the thunderstorm clouds give rise to some kinds of very rapid and characteristic field variations, which are responsible for the disturbance noise of the radio receivers.

By a mere chance already in 1929 at a field station located not far away from Uppsala we were able to observe these rapid field variations by cathode ray oscillographic records. An antenna circuit operated on flashes developed within a few kilometers' distance. The oscillograms were taken directly and thus without an amplification set. The antenna circuit was operating with such a high value of its resistance that the main E variations to some extent became oversteered. The oscillograms were recorded by a rotating drum. The method allowed the extension of the records during longer time periods. A record is reproduced in Fig. 1.* The main discharge with its steep front and the following variation do not show any superpositions. Before the main discharge between a and b we observe characteristic pre-discharges. The record became one of our first opportunities to obtain an oscillogram of the typical pre-discharges of a flash. In Fig. 2 we reproduce a divergent case: before the main discharge typical pre-discharges are visible. The main discharge, that is of a similar variation type as in Fig. 1 contains already in its steep frontal parts superpositions of a rapid field variation character. Typical rapid variations above the

* The main part of the illustrations has been placed at the disposal of the JOURNAL by courtesy of the Royal Swedish Academy of Science.

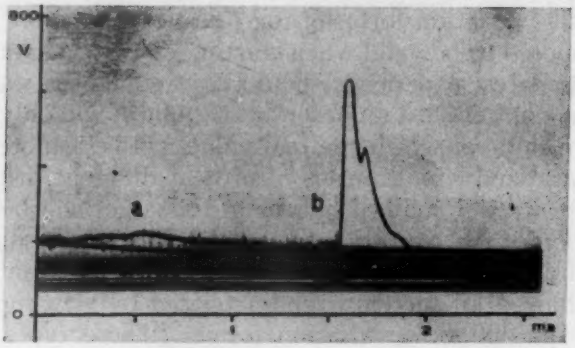

FIG. 1. A lightning with typical predischarges, recorded by a cathode ray oscillograph in 1929 at Uppsala.

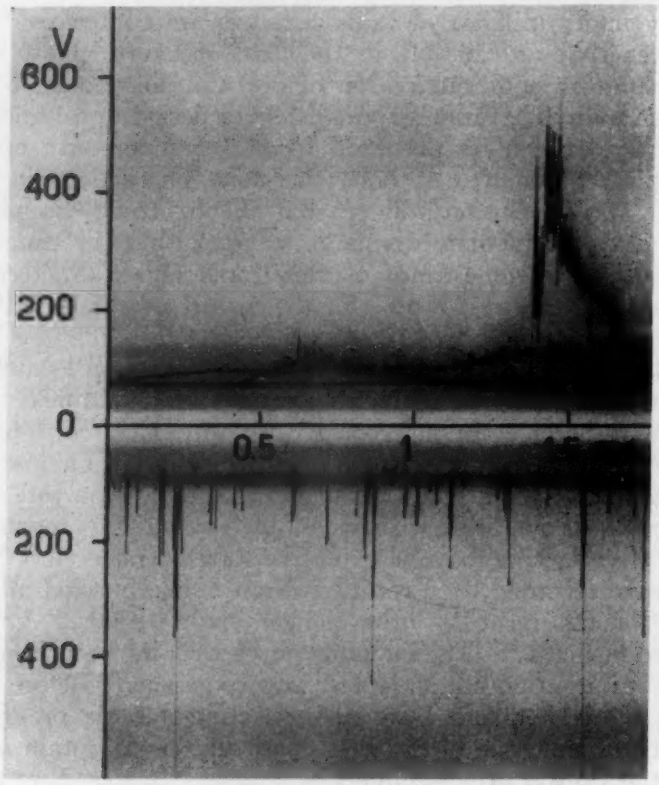

FIG. 2. A lightning oscillographed as in Fig. 1 showing rapid variations recorded in 1929 at Uppsala.

whole time basis are visible on the negative side of the oscillogram. With regard to the rotation of the drum these rapid variations may have occurred during some other time period than that one of the main discharge. A most typical case is reproduced in Fig. 3. One of the

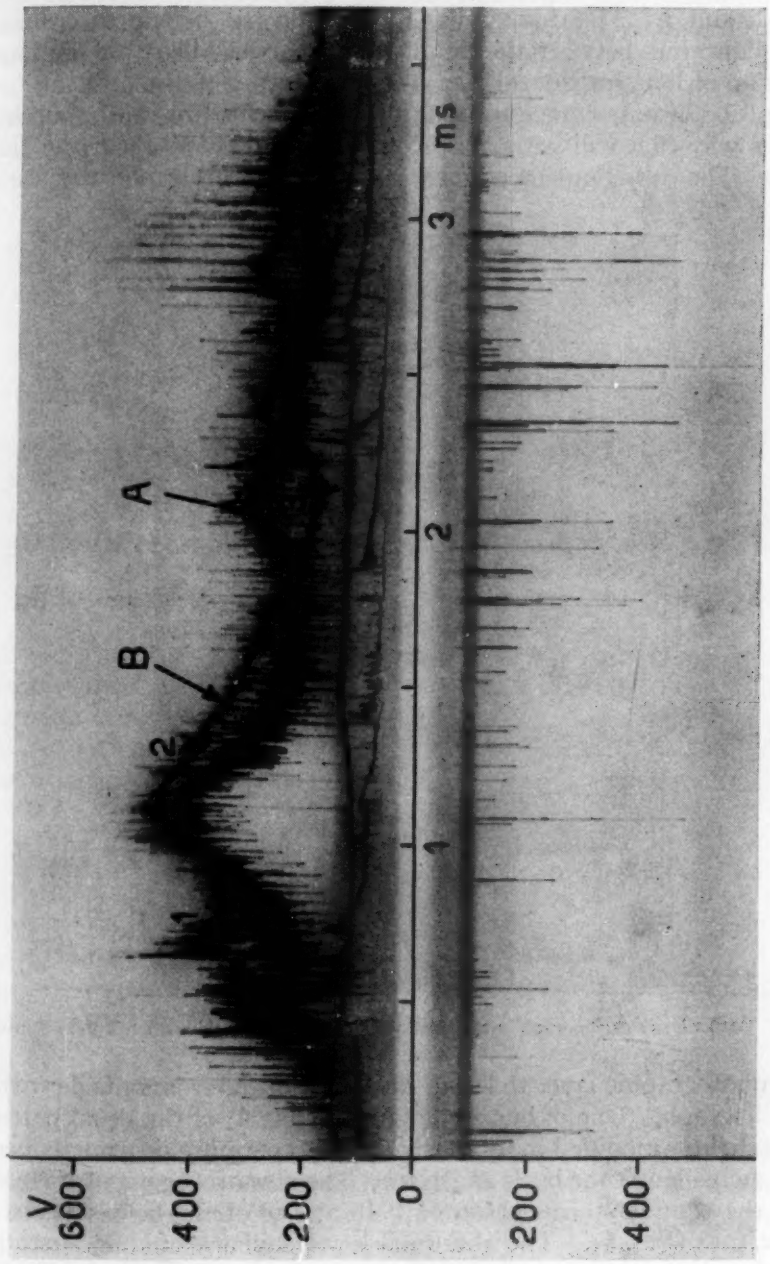

FIG. 3. Lightning discharges with typical differences of superimposed rapid variations recorded in 1929 at Uppsala.

discharges marked with A is very heavily superimposed, another one marked with B shows superpositions especially at some regions marked with 1, 2 and 3. The discharges of Fig. 3 do not belong to ordinary vertical lightnings between the cloud and the earth. They are produced by a group of long horizontal discharges between clouds.

It will be of importance to perform the described recording method in such a way that will permit a record during long and recurring time periods. The development of such a method is based upon the use of

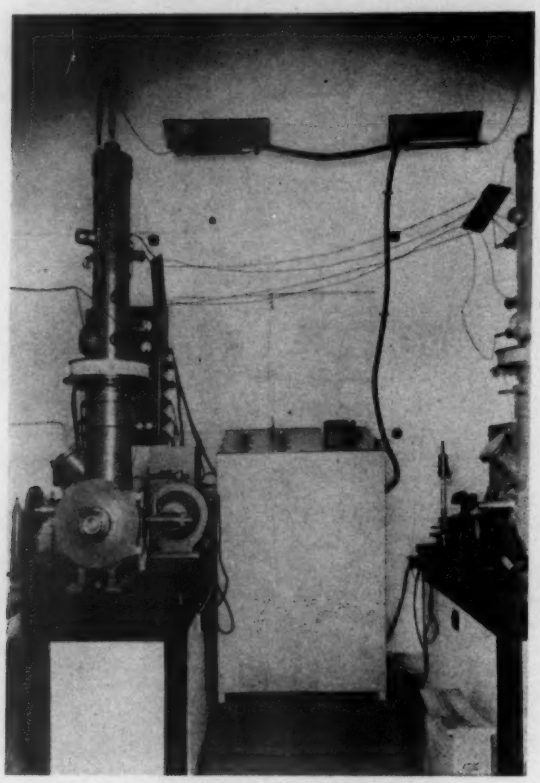

FIG. 4. Cathode ray oscillograph equipment at the Institute's field station Löfsta-Funbo.

a fixed photographic layer that can easily be shifted from outside within the oscillograph. One of our oscillographs (Fig. 4) of the usual pattern (1) was slightly modified in its construction to permit a continual operation of such a long time basis as 20 cm. The new arrangement was used during the thunderstorm season of 1946 at one of the field stations of the Institute (Fig. 5). The abnormal low frequency of thunderstorms in Sweden during this season prevented us from obtaining any flashes of such a vicinity that allowed us to record without amplification. Hence the oscillograph had to be operated with a slight amplification

without disturbance influence. It was of a special interest to try to record the superimposed rapid variations during so long a time period as possible. We were especially interested in receiving records during the slow-moving after-discharge period of a flash. The method necessitated such an over-steering of the main and multiple discharges that these could not be visible on the oscillograms. Two typical records are

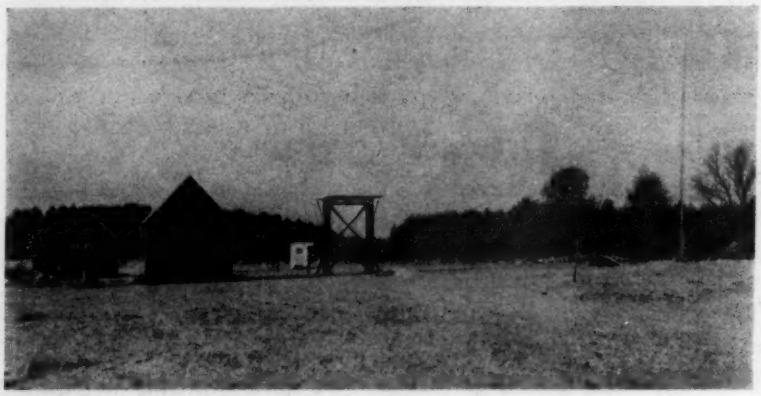

FIG. 5. Research station at Löfsta-Funbo at a distance of 12 km. from Uppsala.

reproduced in Figs. 6 and 7. Both records are oversteered and thus lacking of the frontal parts of the lightning discharges. The following decreasing regions are superimposed by rapid variations of the field force. An examination of the oscillograms confirmed our earlier observations. The lightning discharge mechanism especially in its

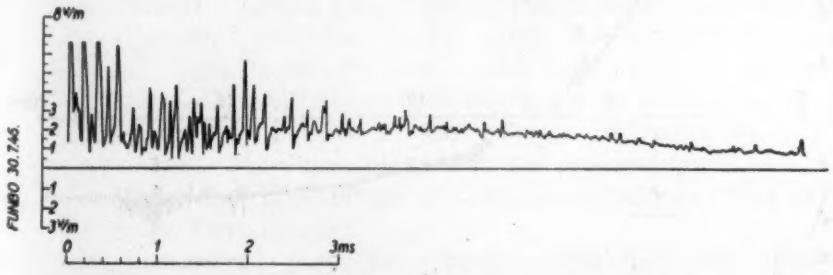

FIG. 6. Record of lightning discharges using long time basis.

after-discharge periods is thus characterized by groups of superimposed rapid field changes, which are aperiodic or quasiperiodic. It was not possible to obtain any typical regularity in the appearing of the field variations, when we try to consider them with regard to the development stages of the lightning discharge as a whole. Another interesting oscillogram layed out is reproduced in Fig. 8. The flash consisted in

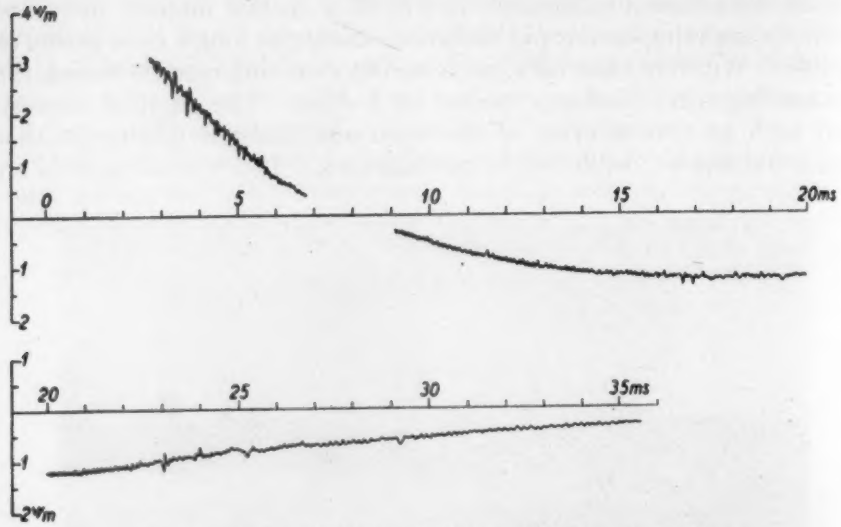

FIG. 7. Record of lightning discharges using long time basis.

this case of the main discharge followed by some multiple strokes located in the region before A of Fig. 8. During 7 milliseconds marked with B–C typical superimposed rapid field changes are occurring. They must be explained as stray after-ionization discharges within the main channel. Later on we observe that similar field changes occur at E and

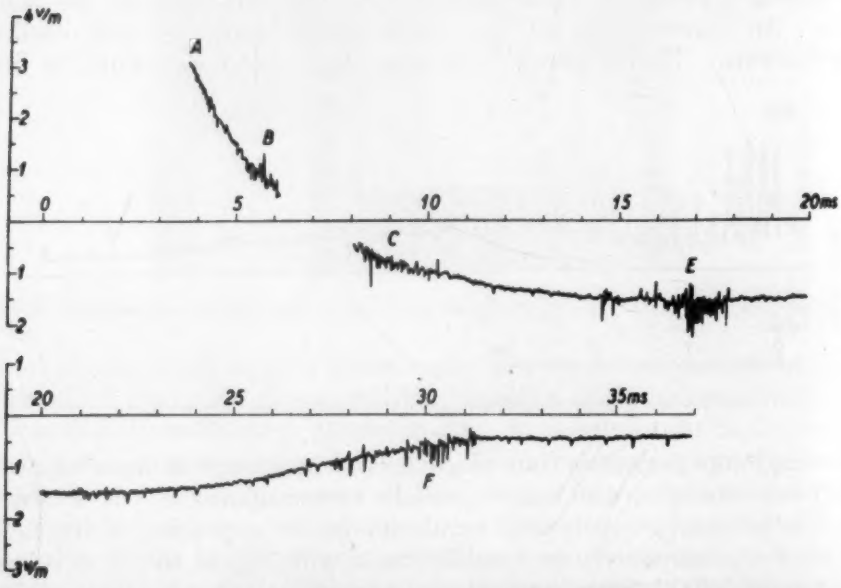

FIG. 8. Record of lightning discharges with repeated higher intensity of superimposed rapid field variations.

F. These periods must be considered as a first beginning of new multiple strokes in form of pre-discharges. If the active field force in these two cases had reached a sufficient intensity, multiple strokes should have followed.

The lightning mechanism, as we have already pointed out, must be considered as a gradual discharge progress of a long duration. If we include initial discharge processes, pre-discharges, main and partial discharges, slow-moving after-variations and repeated small after-discharges the total discharge duration of an ordinary flash must be of the order of seconds. Of this time only usually a few hundreds of microseconds are covered by such main and partial discharges that transport heavy currents in the path of the flash.

The characteristic noises in a radio receiving set during a thunderstorm allow us by a special arrangement to estimate the duration of the total discharge procedure of a lightning. Rapid field changes already discussed represent the casual and predominant source of generating noise in radio receiving sets. Hence the observing method has been applied by the use of an antenna circuit combined with a radio receiver, e.g., tuned at 600 m. or meter wave-length. The circuit had to be connected with a cathode ray oscillograph. Another simultaneous control arrangement was applied by the use of an aperiodic amplifier by which the main and multiple strokes of the lightnings were simultaneously recorded. A slow-moving time axis was used, thus the strokes appeared as straight lines. The noise from the radio receiver was on the other hand spread out over long intervals. Groups of such records are reproduced in Fig. 9, where the rectangles indicate the extension in time of the radio disturbances on a receiver tuned at 600 m. wave-length. The vertical lines are marking the time and occurrence of main and partial discharges. In the lower part of Fig. 9 we observe especially lightning discharges preceded during more than 0.5 sec. by initial disturbances. This is not the case in the upper part of the figure, where lightning discharges start without a period of pre-discharges. The explanation may be that some lightning discharges are lacking initial discharges. More possible is that the pre-discharges have such small amplitudes that they did not provoke disturbances in the receiver tuned at 600 m. wave length.

We have observed that two selective radio receivers, tuned at different wave lengths, are not similar in disturbance sensitivity, when the same flash is considered. It is possible to observe by a special method, how the frequency regions in the disturbance groups of a lightning are shifting. The method consisted of a simultaneous record on a two beams' cathode ray oscillograph, that was connected with two receivers tuned at two different wave lengths. Such a simultaneous record is reproduced in Fig. 10. The disturbances on the 18.000 m. band are all of a short total duration. The simultaneously recorded

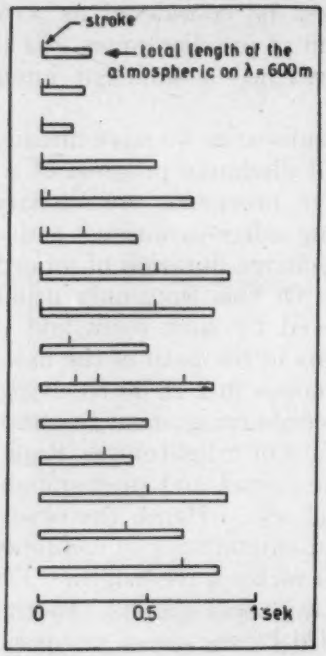

FIG. 9. Disturbances in radio receiver in relation to arrival of lightning discharges.

disturbances at the wave-lengths of 600 m., 1,000 m. and 2,000 m. are composed of coherent groups of durations sometimes up to one second.

FIELD VARIATIONS AT GREATER DISTANCES OF LIGHTNING PATHS.

Necessity of New Recording Methods.

A record of the total duration of the discharge process in the vicinity of the channel offers, as we have seen, complications that depend on the existence and spreading out with time of the superimposed rapid field variations. At greater distances these variations are acting with such small amplitudes that we will not be able to record them, if we do not use a very high amplification. If we for instance should try to operate with a high amplification during a thunderstorm season, the result would be very complicated records originating from the most different and shifting sources of flashes. Hence it will always be of importance, when we have to record lightning discharges at greater distances, to diminish the amplification level to a lower and convenient value. Such a method will also offer certain difficulties depending on the long duration of the total discharge procedure that includes, as already mentioned, consecutive groups of discharging phenomena. The prominent difficulty in such records is the necessity to lengthen them out in time during a sufficiently long recording period without the loss of the dissolving power. The problem was solved by a special construction introduced on

one of our oscillographs of the usual pattern. The instrument was provided with a vacuum tight rotation device, where a tombac tube was used. The device allowed a continuous rotation speed of the paper of 30 meters per minute. The special device of the oscillograph is il-

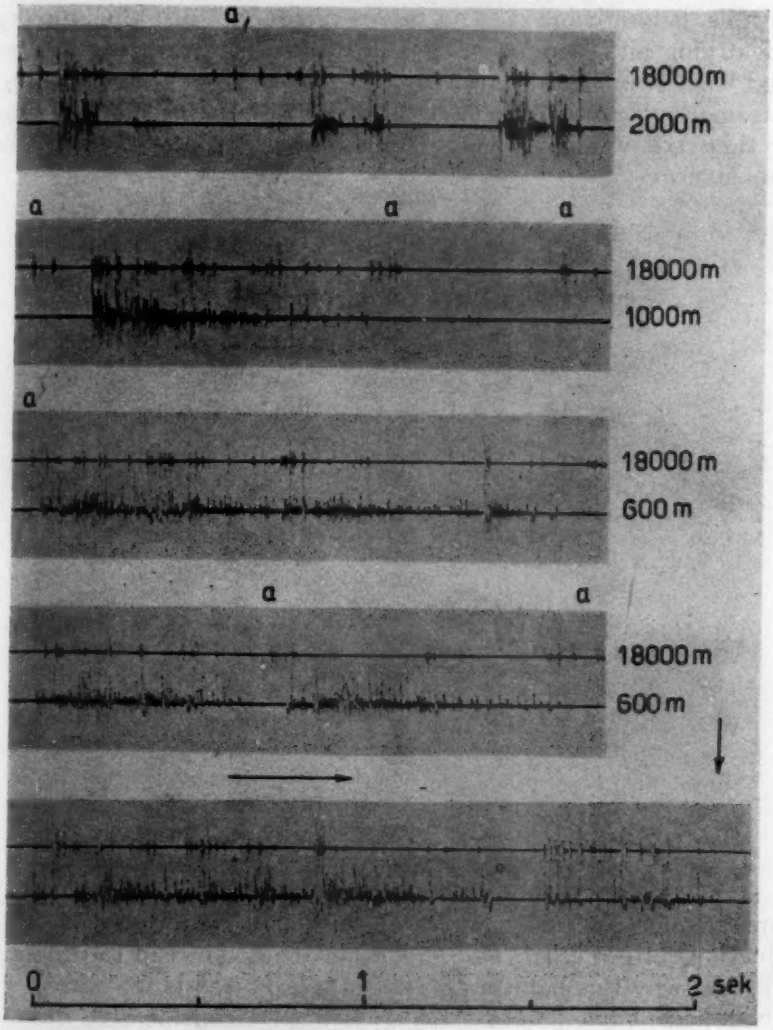

FIG. 10. Simultaneous records in radio receivers of atmospherics at two wave-lengths.

lustrated in Fig. 11 and is marked with A. The rapid rotation of the paper within the vacuum vessel of the oscillograph offers considerable difficulties owing to the humidity content of the photographic recording layer. If the paper, when being put forward, gives off considerable quantities of water no definite concentration of the electron beam will

be obtained. This causes disturbances both in the accuracy of record and in deviation sensitivity. What this means appears from the circumstance that the recording paper, which is rapidly put forward in vacuum, has a surface of 2,500 cm.^{2} This paper quantity must be continually exposed in vacuum in such short periods as 60 sec. The paper rolls, before being used in the oscillograph, must thus undergo a careful drying and evacuating procedure in a separate vacuum tank, marked with B in Fig. 11, during a period of about a week. The recording method consisted of a combination of the oscillations from a linear time axis with the continually advanced rotation of the photographic layer.

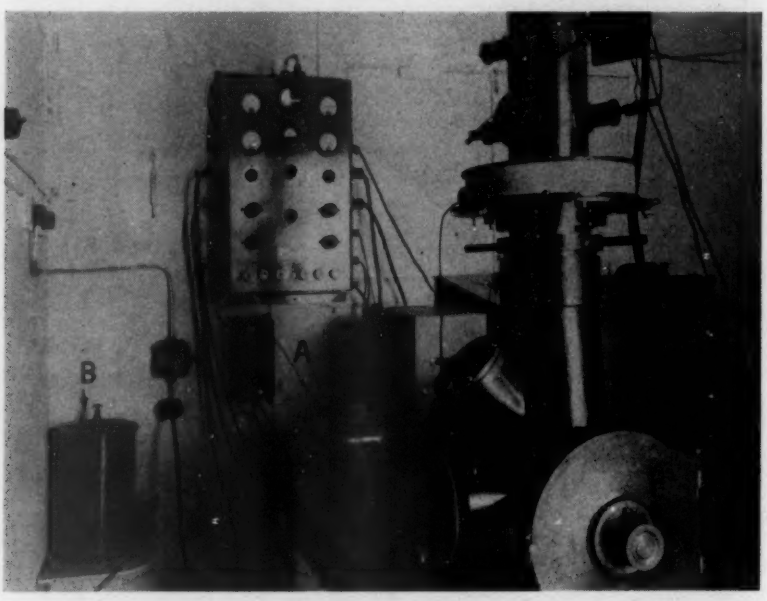

FIG. 11. Details at a cathode ray oscillograph of a specially constructed high speed rotating device.

An introductive example of the method is reproduced in Fig. 12, which is a record of a lightning discharge at a distance of 150 kilometers. The reason why this lightning has been reproduced is that according to the experience gained from a selection from a considerable number of records the lightning discharge can be considered as particularly typical and explanatory.

The total record comprises a time of $\frac{2}{3}$ second and the time of the oscillogram passes from its upper to its lower part as is marked by the arrow to the left of the figure. The oscillation time variation is marked with the two arrows above the time axis of the figure. The record is to some extent disturbed by a small superimposed high-frequency, which

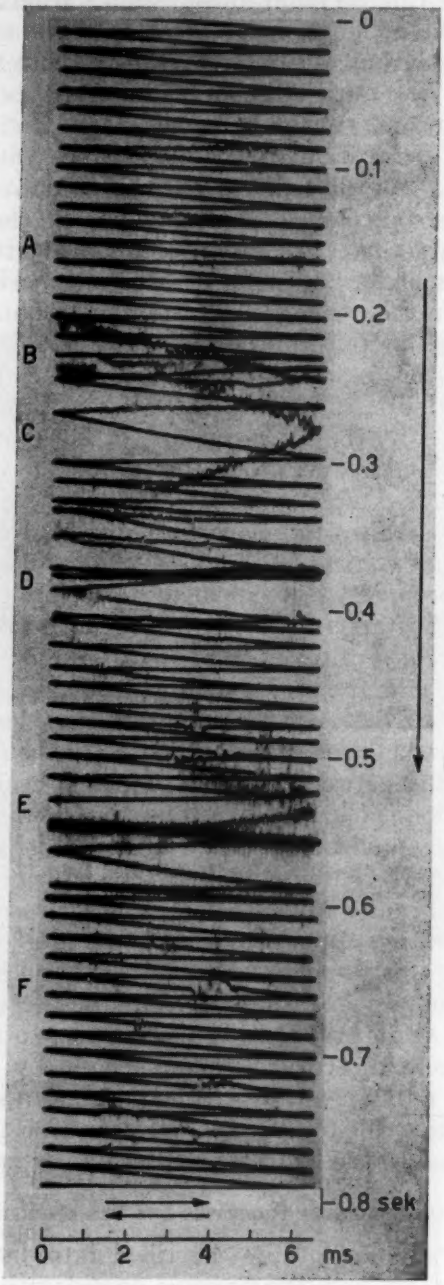

FIG. 12. A record of a lightning at a distance of 150 kilometers.

originates from the English radio transmission station at Rugby. From an inspection of the oscillogram follows that at the seventh oscillating sweep from above a group of pronounced disturbances is occurring that are marked with A. Initial discharges of this type often precede a lightning discharge and consist of small sparks and glow discharges. These are due to dislocation of volume charges within the thunderstorm atmosphere. As will be observed further on it sometimes occurs that the discharge processes of a thunderstorm cloud cease at this stage. Pre-discharges that are directly connected with the subsequent main lightning discharge beginning at a region marked with B, have been oversteered in the oscillogram. In order to obtain impulses with smaller amplitudes on the same oscillogram as those ones of higher amplitudes it was necessary to oversteer the later ones, from which follows that essential parts of them will not be visible. As a result of the blockade caused by the second great world war it was not possible to obtain photographic paper from abroad for the recording work of 1945 at the Institute. We were obliged to use a Swedish product with limited sensitivity. When this paper was used, it was sometimes very hard to record rapid voltage variations in the oscillographs. It would in this case have been very convenient to work simultaneously with the two recording oscillographs connected with the two separate amplifiers regulated on different sensitivity levels.

In the recorded case the proper main lightning is beginning at C and a partial discharge at E. Also the amplitudes of these impulses are too high and oversteered. From an examination of the section between C and E, i.e., the time between the two proper lightning discharges follows that this section is filled up by a considerable number of discharges containing smaller amplitudes. They are caused by glow discharges and smaller sparks, which are sequel from the heavy main discharges at C. Such secondary discharge effects are observed after the partial lightning at E and are especially prominent at the F region of the oscillogram. It is worth mentioning another detail in this connection. No marked superimposing of the rapid impulses occurs after the main discharge at C. On the other hand this is the case after the partial discharge at E. There the curve is characterized by an intense superimposing of rapid impulses, of which the generation is explained by an accelerated ionization due to the repeated ionization that develops both in the main channel of the lightning and in its partial branches.

INITIAL DISCHARGE PROCESSES AND PRE-DISCHARGES.

From the background of the described introductory and typical lightning discharge we will devote some consideration to the problem of the transient phenomena occurring before the main and partial discharges of flashes. The initial discharge processes, which seem to be extended over long time intervals, have such small amplitudes and are

so quickly attenuated that they must be recorded in more adjacent regions of the lightning channels. A record of them will not be possible by the method of this chapter. With regard to their existence we refer to what has been discussed in relation to the Figures 1–3 and 6–8 and to the occurrence and extension of the noise of radio receiving sets (see Figs. 9–10) exposed not too far away from lightning flashes.

The method is on the other hand very fitted, when we have to study the pre-discharges. The pre-discharges are composed by groups of partial impulses, which as is well known gradually proceeds along the developing lightning path. Some typical oscillograms containing pre-

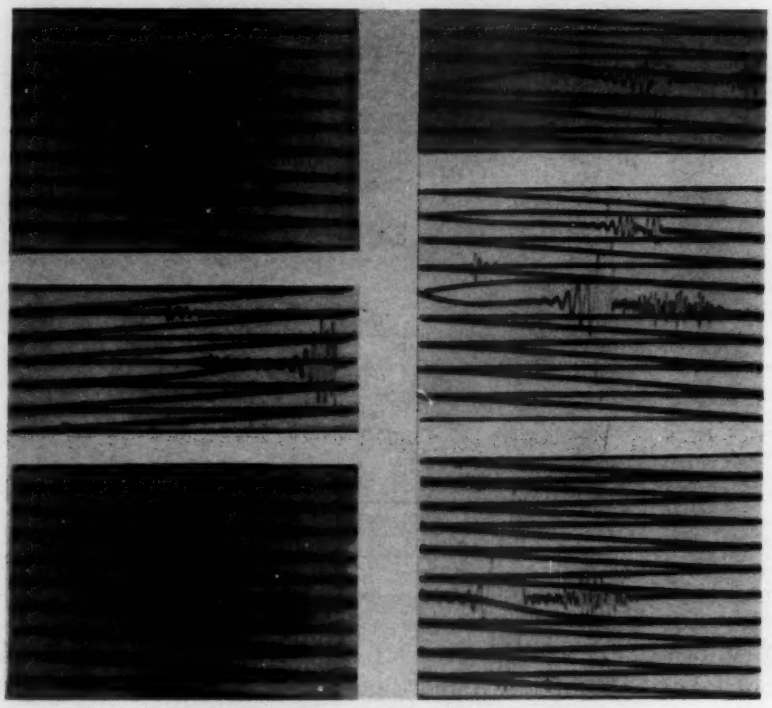

FIG. 13. Typical oscillograms of pre-discharges with following lightning strokes.

discharges followed by main and partial discharges are reproduced in Fig. 13. They have been re-drawn in Fig. 14 in order to make them clearer. There is a difference between the six flashes, where the pre-discharges are marked with *a* and the proper lightning including main and partial discharges with *b*. In the three lowest oscillograms of Fig. 14 we find that there is a calm period before the beginning of the main discharge. This is not valid for the other oscillograms, which also have a more typical slow after-variation. The variation form of the discharge procedure as exemplified by Fig. 14 has earlier been observed (7).

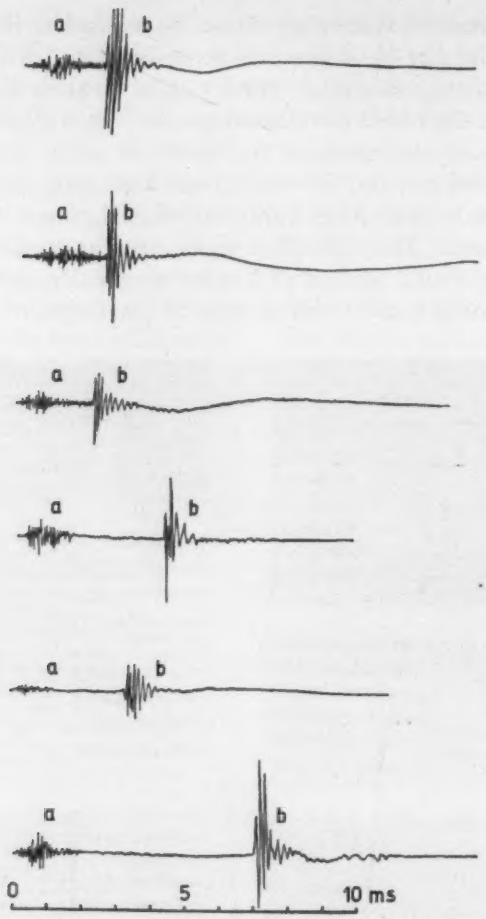

FIG. 14. Pre-discharges *a* and lightning main and multiple discharges *b* laid out.

A problem of special interest is to look for such pre-discharges that are not followed by a subsequent main discharge. The meteorological definition of a thunderstorm is an expression of a certain limited level of the field force, that must attain such an intensity that a disruptive discharge in form of flashes occurs. The initial situation, that is when the field intensity is not high enough to start a proper lightning discharge is not by the meteorologists classified as a thunderstorm. From a purely physical point of view there will not be any appreciable differences with regard to the field conditions and the distribution of the charges in the two stages.

It will thus be possible to detect pre-discharges, which are not followed by main and partial lightning discharges in such cases, when the intensity of the former has not been high enough to start a subsequent flash. Such typical pre-discharges are reproduced in Fig. 15.

The two lowest discharges have a comparatively long duration. Sometimes a pre-discharge occurs that has a certain sequence of impulses with a corresponding comparatively slow equivalent frequency. It

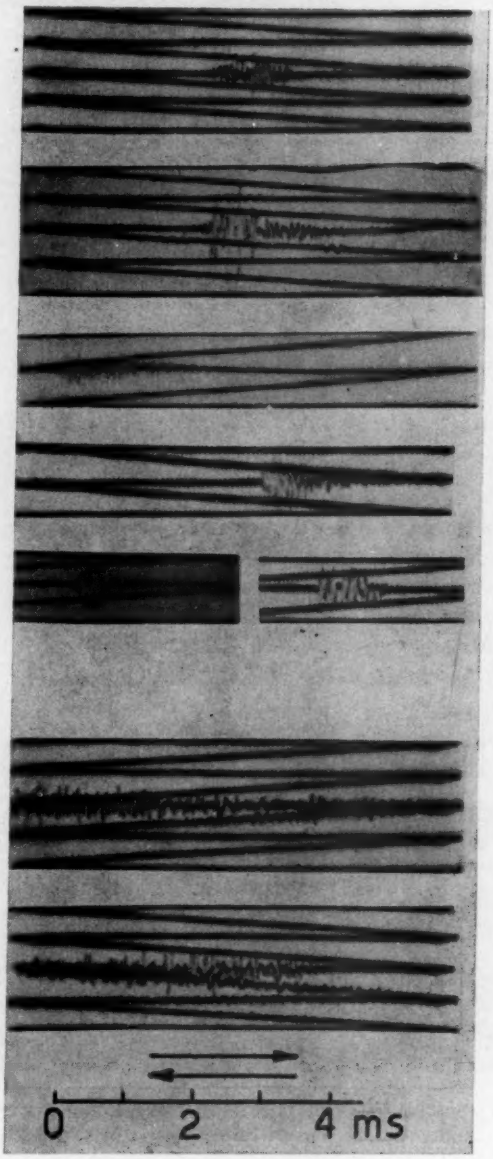

FIG. 15. Pre-discharges lacking main and partial lightning strokes.

happens that a following pre-discharge shows a more rapid sequence of impulses corresponding to a higher equivalent frequency caused by an increase of the ionization in the active regions of the flash. Such a

typical situation is illustrated by Fig. 16. A pre-discharge occurs at *a* with a corresponding equivalent frequency. At about 0.2 second later a new pre-discharge is following, which contains a considerably higher equivalent frequency. This pre-discharge is followed by a marked main lightning stroke.

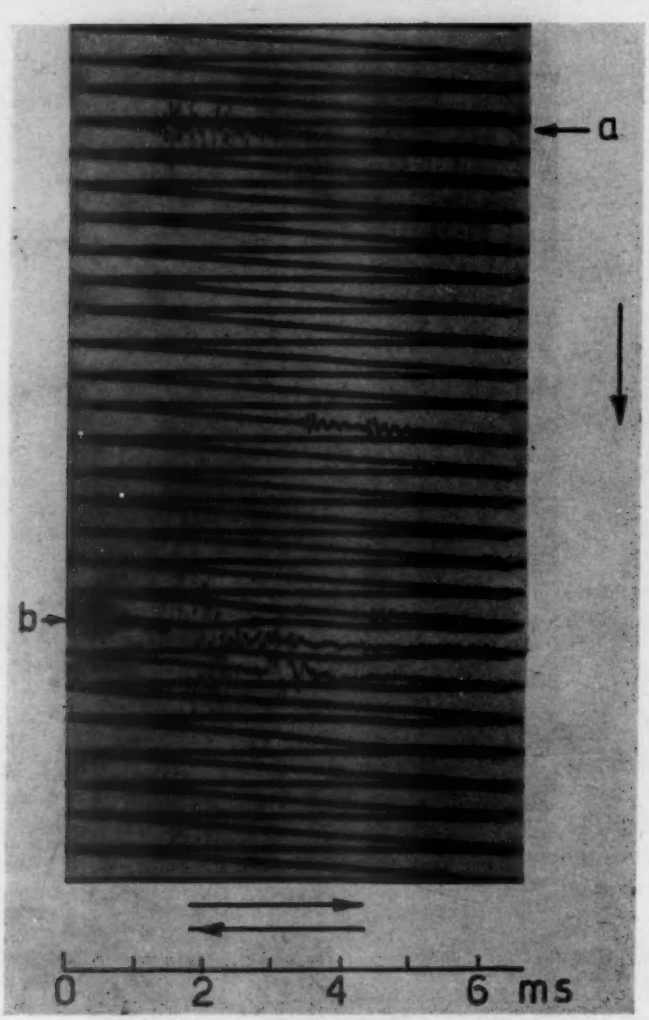

FIG. 16. Pre-discharges lacking lightning stroke, followed after 0.2 sec. by another pre-discharge with lighting stroke.

The method described above will not be convenient in recording the structure and variation forms of main and partial discharges. The used recording velocity is too slow for these rapid variation forms. We will try to analyze and discuss them in a following chapter.

SLOW-MOVING AFTER-VARIATIONS.

In the lightning discharges there sometimes appears a slow-moving after-variation, which consists either of one-half or one entire period. Such forms are visible in the upper curves of Fig. 17. A lightning discharge, which has travelled at greater distances, constitutes, as we know, an atmospheric. The slow-moving after-variations are thus

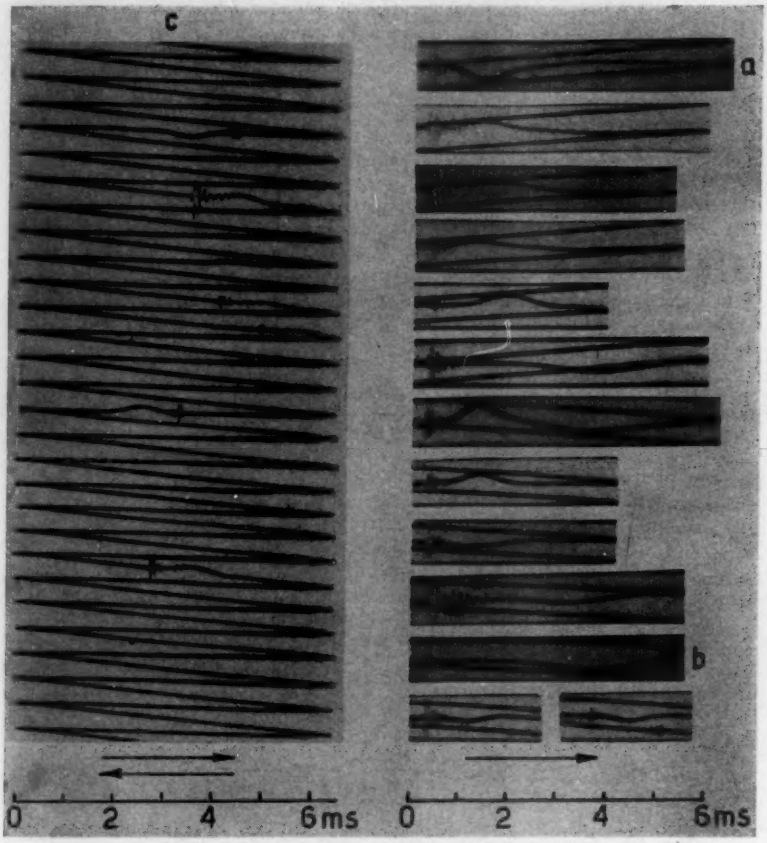

FIG. 18. A swarm of atmospherics with similar after-variations.

FIG. 17. Atmospherics with slow-moving after-variations with time differences *a* and *b*.

called the tail of the atmospherics (6). From some statistical examinations it follows that the time difference between the main discharges and the sequent slow-moving parts is increasing with the distance. A definitive physical explanation of the successive transformation of the slow-moving variations is not possible with available and limited measurements, but as an explanation it has been supposed that the successive transformation of the variation form is in some way caused

by different group velocities of the propagating impulses. From our point of view a definite answer to the problem will be possible, when the impulses in their transformations are simultaneously recorded at some observation stations situated at fitting distances from the thunderstorm source.

The lightning discharges at greater distances—the atmospherics—with slow-moving after-variations are sometimes characterized by shifting time differences between the first occurring rapid part and the slow-moving after-variations. Also their curve forms are varying.

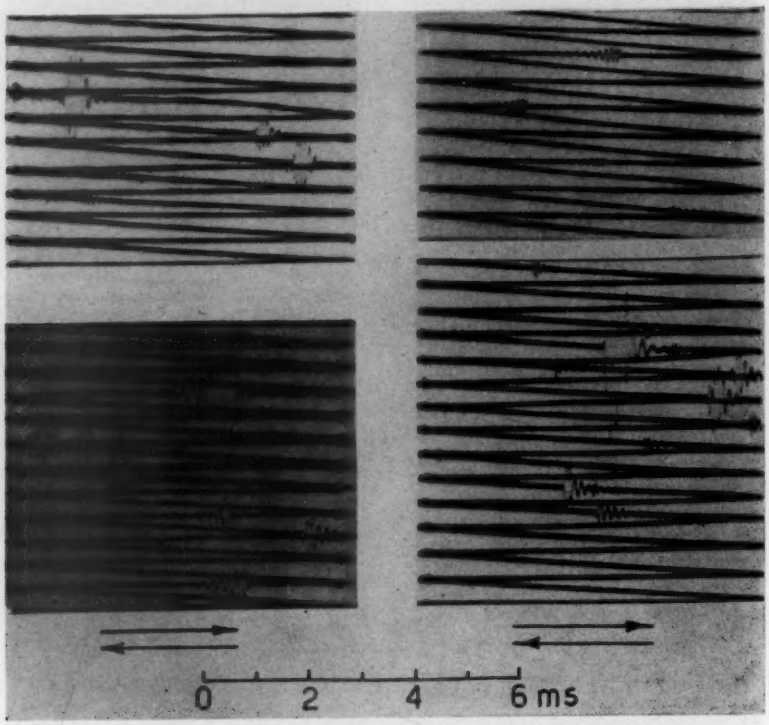

FIG. 19. Consecutive atmospherics from the same lightning path.

Typical examples are reproduced in Fig. 17, where the difference between the curve marked with *a* and the corresponding one marked with *b* is very significant.

We have on the other hand observed divergent cases of which Fig. 18 is representative. The recorded swarms of the atmospherics of this group all showed both a similar variation form and a similar time difference as estimated from the initial rapid oscillations. These later types, as already mentioned, are following after main and multiple or partial lightning discharges. When the swarms are lacking slow-moving after-variations, they are characterized by a pronounced conformity showing

divergences with regard to amplitudes. Their time differences are of the order of some hundredths of a second and in some cases they must have their origin from the same lightning path. Some typical records of such swarms are reproduced in Fig. 19.

We observe sometimes swarms of rapid variations, where the time differences have shorter intervals than a few milliseconds. In such a case the successive atmospherics are caused by multiple lightning discharges in the same path. As will be demonstrated further on successive lightning discharges following the same path will in most cases show a uniform variation mainly uni-directional. The impulse forms of Fig. 20 are typically oscillating, which means a pronounced transformation from the unipolar variation form during the long passage from the source. It is not possible to give an explanation to this transformation

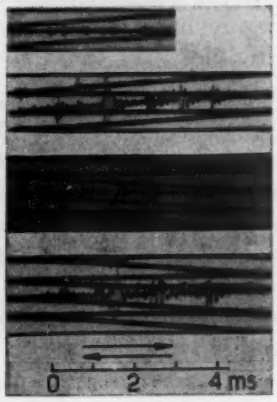

FIG. 20. Long distant atmospherics of oscillating type with shorter time intervals.

until simultaneous records of atmospherics at different distances from the source are available.

REPEATED SMALL AFTER-VARIATIONS.

When considering again the foregoing Fig. 11 we notice at the region marked with F some groups of repeated discharges classed as after-variations. They are following in the lightning channel earlier passed by the partial discharge marked with E in Fig. 12. It is easy to explain the successive development of these small after-variations. A lightning discharge represents a pre-dominant disturbance within the thunderstorm both with regard to the main ionization channel and its smaller ramification branches. The actual lightning discharge must be followed by extended dislocations within the electrostatic field regions around the discharge channel. Obviously before a full deionization of the lightning channel has come into action, groups of repeated smaller current pulses or after-variations are developing within the channel.

Their feeding regions, which will cause their field variations to be comparatively rapid, will be followed by equivalent frequency components audible in radio receivers. The small after-variations are very often audible over time periods up to one second as reckoned from the proper lightning discharges. The repeated after-variations are usually causing disturbances above a wide frequency spectrum. Similar variation types are sometimes occurring as superpositions more closely with regard to time distance of the main lightning discharges. An example of this is given in the foregoing Figs. 6–8. In some lightning discharges parts of the main or the multiple discharge curves are characterized by extended rapid and repeated superimposed field variations of similar character as the small after-variations. It is not astonishing why the disturbances in radio receiving sets are producing such shifting characters when the effects of consecutive flashes are considered. A more developed measuring technic will surely be able to make these interesting problems intelligible.

(*To be continued*)

TELEVISION.*

BY

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Many of you may have followed the development of television from its early stages. You may remember the coarse-grained, postage-stamp size pictures of the twenties and recall the improvement as television liberated itself from the shackles of mechanical scanning devices. Ultimately, as the possibilities of electronic methods were realized more completely, you found yourself witnessing black-and-white pictures, sharp and full of detail, of scenes picked up under almost any condition of illumination.

From the very beginning it was clear that the eventual goal of television was reproduction in natural color. As in photography, however, it was obvious that television would first have to be developed on a monochrome basis. As a consequence, first attention was devoted to solving the many difficult fundamental problems inherent in television generally, problems applicable to both monochrome and color. Throughout this development, however, the eventual requirements of color were kept in mind.

From time to time since 1940, color television demonstrations have been given by RCA and NBC to show the progress of their work. But no system was discovered which we considered basically sound enough to be offered to the public. At a demonstration of mechanical *sequential* color television made by RCA in December 1945, we pointed out that, in our opinion, any mechanical color system is outmoded and that only through the use of all-electronic means can a system of color television be developed which will be fully satisfactory for public use. A great step in the direction of obtaining such a system was taken in the recent development by RCA of the *simultaneous* electronic color television system. This simultaneous system is completely compatible with existing monochrome television and has other important advantages over any sequential system. The transition from monochrome to simultaneous color television can be made at any time in the future without obsolescence of the monochrome receiving and transmitting equipment, and it can be developed side by side with monochrome television without fear of obsolescence of the latter and without loss of investment by the public, by manufacturers and by television broadcasters.

The progress that has been made so far in color television—and it is

* Presented before The Franklin Institute, April 30, 1947.

not inconsiderable—has been due to the efforts of many men, working in close cooperation. It is my privilege today to present to you some of the fruits of their labor.

Before entering upon the peculiar problems of color television, it may be well to recall, in brief, the general plan of a normal monochrome television system (Fig. 1). The scene to be transmitted is projected by a lens onto the signal screen or mosaic of the pick-up tube, here an iconoscope. This mosaic consists of a photosensitive, insulating surface coupled by capacity to a metal backing, the signal plate, which is connected to the picture amplifier. As the luminous image is projected on the mosaic a charge distribution corresponding to the image is built up

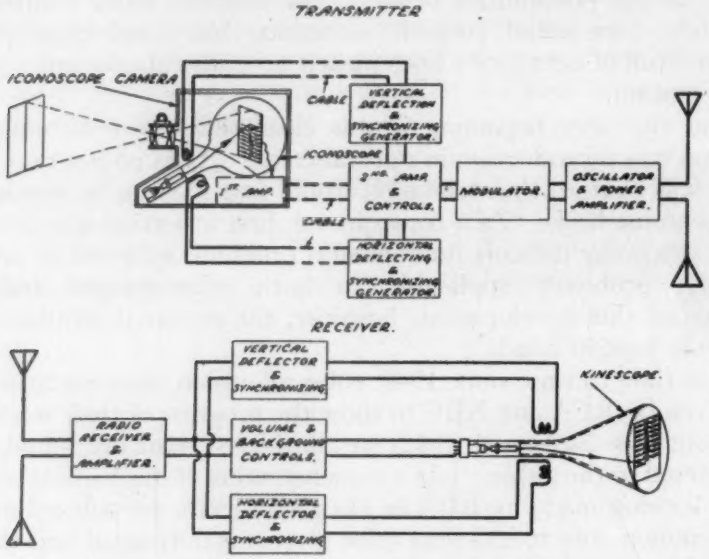

FIG. 1. Schematic diagram of an electronic television system.

on the insulating surface by photo-emission. A high velocity electron beam sweeps over the surface in some 500 parallel horizontal lines once every thirtieth of a second. As it strikes any particular point of the mosaic, it brings its potential back to a certain equilibrium value and thus liberates the charge stored by the light image during the preceding thirtieth of a second. An equal charge of opposite sign, bound on the signal plate, is freed and determines the instantaneous voltage of the first grid of the amplifier in correspondence with the brightness of the particular picture element under consideration. The pickup tube thus generates, in the course of a thirtieth of a second, signal voltages corresponding to several hundred thousand such picture elements in orderly succession, as the beam scans the mosaic. This voltage variation is amplified and permitted to modulate an ultra-high-frequency radio

wave which is broadcast from the transmitter antenna. After demodulation and amplification in the receiver, the same signal controls the electron current in the scanning beam of a viewing tube, which scans a fluorescent screen in unison with the scanning beam in the pickup tube. The fluorescent material converts the energy of the beam into light, so that the observer sees the picture originally projected on the iconoscope mosaic reproduced on the screen of the viewing tube.

Although the basic plan, just outlined, of an electronic television system has been adhered to since the beginning of electronic television, many important refinements have taken place in its several components. Some of these, insofar as they are of importance in color television or find application in today's demonstration, merit a brief description at this time.

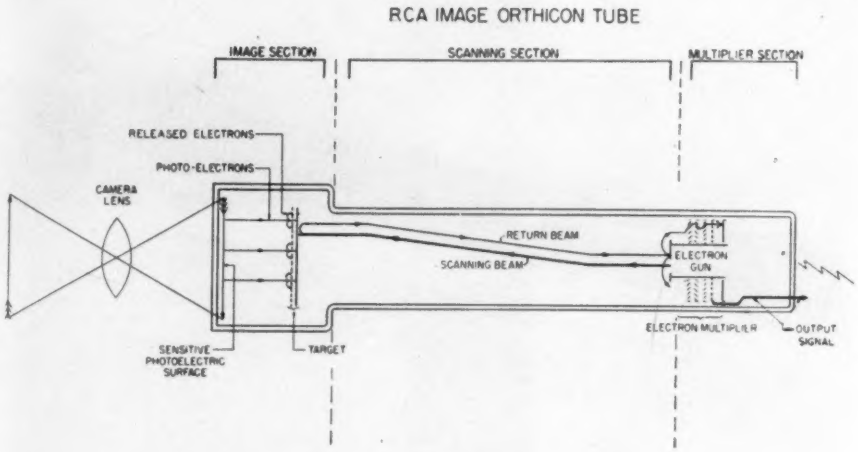

FIG. 2. The image orthicon (schematic diagram).

Since earlier television pickup systems required excessive illumination and were hence severely restricted in their scope, considerable research effort was directed at increasing the sensitivity of the pickup tube. The culmination of this effort is represented by the image orthicon (Fig. 2). The basic elements of the simple iconoscope—the scanning beam and the mosaic—are still there. However, they, as well as the methods of scanning and signal collection, have been greatly changed. The light image is not projected on the mosaic, but on a transparent photocathode. The electrons released from the latter are accelerated toward an extremely fine-meshed target screen in front of the mosaic and, at the same time, focused on the mosaic by the longitudinal magnetic field in which the whole tube is immersed. The mosaic itself consists of a film of blown glass so thin that it has appreciable electrical conductivity through the film but a negligible amount from picture

element to picture element across its face. The incident photoelectrons eject secondary electrons, which are collected by the target screen, and thus build up a charge image on the mosaic similar to that formed by the light image in the simple iconoscope.

The scanning beam, deflected by a transverse magnetic field superposed on the longitudinal field, is incident on the other side of the mosaic. However, while, in the simple iconoscope, it arrives at the mosaic with a velocity corresponding to some thousand volts, it is here slowed down, so that it only strikes portions of the mosaic which have been rendered positive by the incidence of photoelectrons and ejection of secondary electrons. At such points, the beam deposits just enough electrons to return the point to equilibrium potential. The remainder

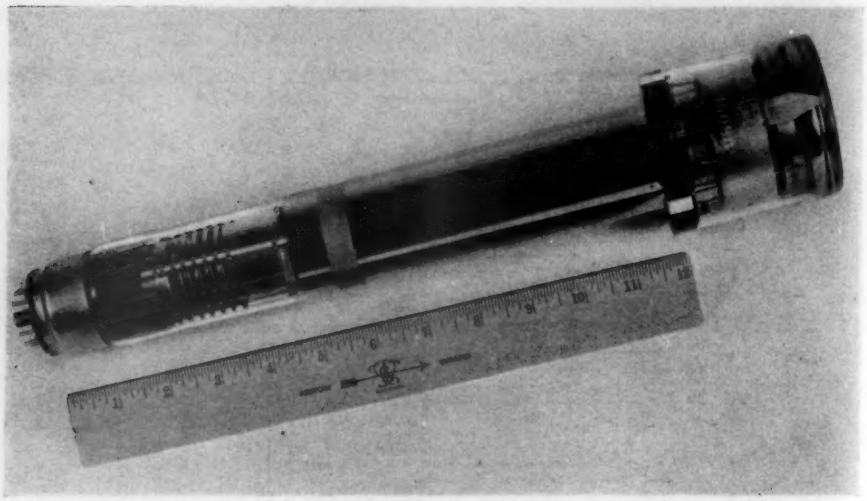

FIG. 3. The image orthicon.

of the beam, which carries the signal by subtraction, returns to the anode disk in front of the cathode and ejects there a current of secondary electrons which is multiplied by a large factor by passage through a "pinwheel" electron multiplier before being applied to a conventional amplifier. The external appearance of this pickup tube indicates its rather complex construction (Fig. 3). While the simple iconoscope represented an advance in sensitivity by a factor of the order of a thousand, the image orthicon has led to a further gain of at least several hundreds. With it any scene can readily be transmitted provided that the illumination is adequate to permit observation with the unaided eye without strain.

A second, very simple, pickup system, which had found favor over a decade ago, has come once more to the fore—partly because more recent

developments in cathode-ray tubes, phosphors, and phototubes have enhanced its sensitivity, partly because of the peculiar requirements of the color television system to be demonstrated today. This is the flying-spot system. It may be applied to the generation of picture signals both from motion picture film or slides and from studio scenes (Fig. 4). In either case the screen of a cathode-ray tube, scanned by a beam of constant intensity, is imaged on the object to be transmitted. The transmitted light, or part of the reflected light, respectively, falls on the cathode of a phototube, whose photocurrent then constitutes the picture signal. The special requirements which the flying-spot tube must fulfill are a very small spot, great spot brilliance, and a very short persistence of the luminescence excited by the beam on the fluorescent

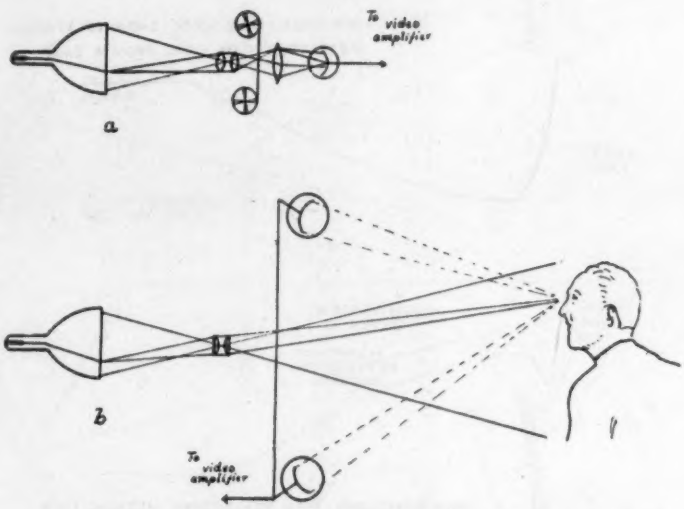

FIG. 4. Flying-spot pickup. *a*. For film transmission. *b*. For studio transmission.

screen: While in a kinescope or viewing tube a persistence of the light excited by the beam for up to 1/30 second only serves to minimize the flicker, in the flying-spot tube a continuation of the light emission for as much as a microsecond gives rise to reduced resolution in the transmitted picture.

In the receiver, also, numerous improvements have taken place since the original introduction of the kinescope. Some of these, such as the design of electron guns to operate at higher voltages and to yield smaller, sharper spots, and the development of efficient phosphors with a wide range of color, have been practically continuous in character. Other important contributions, of relatively recent date, are the employment of metal backing for the fluorescent screen and the utilization of aspherically corrected reflective optics for projected pictures.

A thin, reflecting film of aluminum may be formed back of the fluorescent screen in the following manner: After the luminescent material has been deposited, a very thin cellulose blanket is laid down over it and aluminum is evaporated to a thickness of the order of a hundred-thousandth of an inch. The film, which retains its flat surface after the cellulose has been disintegrated during the baking of the tube, possesses the property of being transparent to high-velocity electrons but opaque

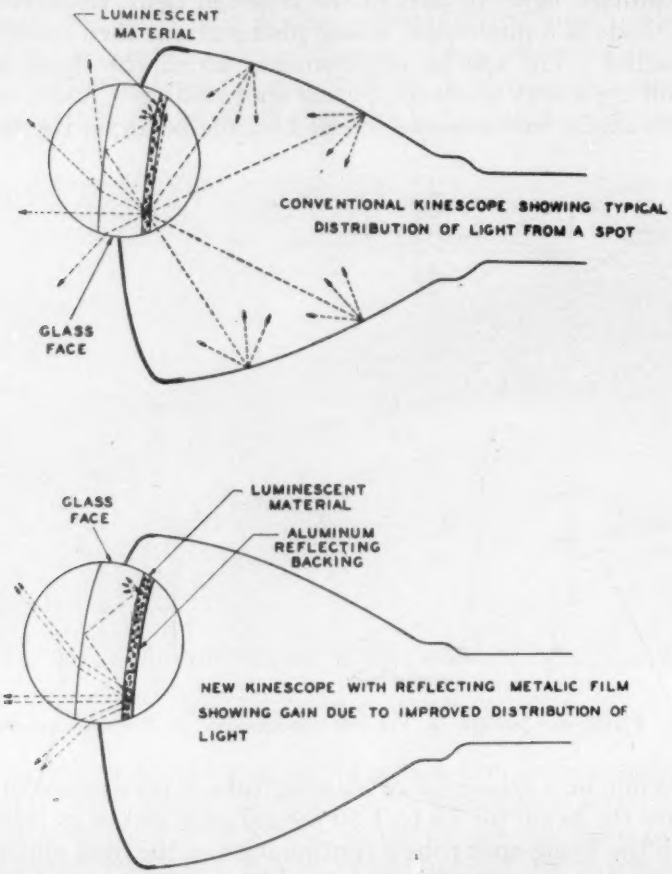
LUMINESCENT MATERIAL
CONVENTIONAL KINESCOPE SHOWING TYPICAL DISTRIBUTION OF LIGHT FROM A SPOT
GLASS FACE
GLASS FACE
LUMINESCENT MATERIAL
ALUMINUM REFLECTING BACKING
NEW KINESCOPE WITH REFLECTING METALIC FILM SHOWING GAIN DUE TO IMPROVED DISTRIBUTION OF LIGHT

FIG. 5. Effect of reflecting film on kinescope screen on light distribution.

to light. Accordingly, light emitted backwards by the luminescent layer is reflected and enhances the forward emission. Without the metal film, this light is partly lost, partly returned to other portions of the screen, reducing the contrast of the picture (Fig. 5). An even more important property of the metal-backed screen is that it remains at anode potential for arbitrarily high operating voltages. As a result, the beam strikes the phosphor with the full energy imparted by the operating voltage, leading to the greatest possible light excitation. In

addition, image shifts due to charging-up of the screen are completely prevented.

If the image formed on the face of the viewing tube is to be projected on a large screen, it is essential that the greatest possible fraction of the light emitted by the kinescope be utilized for the final image which, yet, should have good definition over its entire area. An f/2 projection lens, which can be made to satisfy the latter condition, will transmit at best 6 percent of the available light. The reflective projection system described below increases this fraction to about 30 percent, that is, by a factor of 5, while still maintaining good definition over a field of the order of 50 degrees.

The principle of this reflective projection system (Fig. 6) is reminiscent of the Schmidt telescope of the astronomers. The principal imaging element is a spherical mirror concentric with the kinescope tube

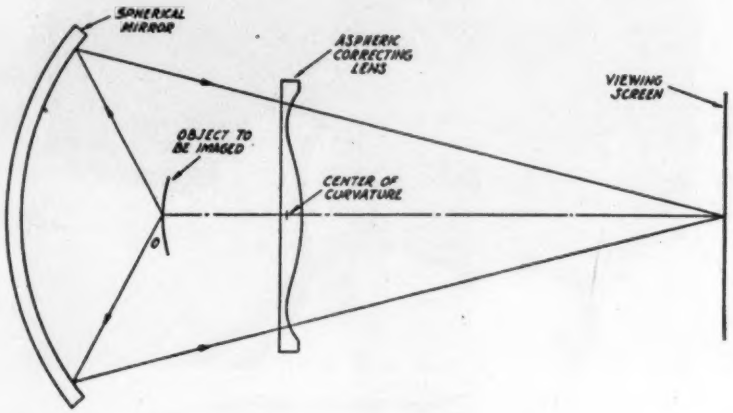

FIG. 6. Principle of reflective projection system.

face. If the viewing screen also is concentric with these two surfaces, the system has the property that the imaging conditions are optically identical for all points of the luminescent screen: the system is free from field aberrations, though invested with very serious spherical aberration. If, in addition, a weak aspheric element is placed at the center of curvature as shown, the spherical error may be nullified on the axis, and because of the symmetry of the system, minimized for all other points of the field as well.

A projector employing an optical system of this type (Fig. 7) and a 70-kilovolt projection tube for producing 15 × 20 foot pictures of brightness and detail suitable for theatre use was demonstrated in New York in 1941.

Returning to television in natural colors, it is of interest to consider briefly some of its future special applications. Color television will by

no means be confined to broadcasting. One valuable use is called to mind by a recent use of black-and-white television at Johns Hopkins University. An invitation was sent out to prominent physicians to watch an unusual surgical operation. The response was such that it

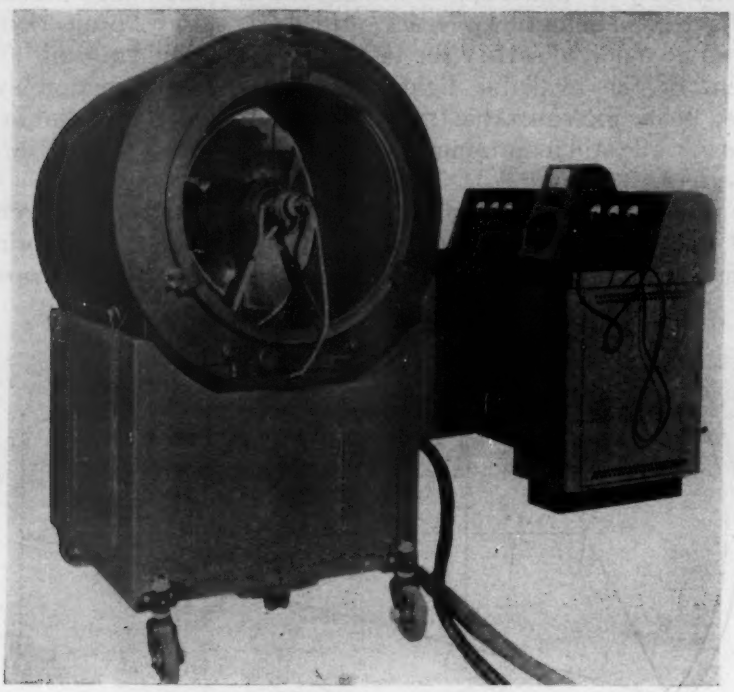

FIG. 7. Theatre television projector.

became impossible for all the visitors to watch the operation directly. Accordingly, a television camera was mounted above the operating table and the image transmitted to receivers, which were watched by the visitors. Some of the latter expressed themselves to the effect that never before had they been able to follow the details of an operation so perfectly. Any one who has had occasion to compare black-and-white and color plates in medical publications will realize how greatly the value of this demonstration would have been enhanced, had the image been transmitted in natural colors. Again, consider the practice of some department stores of demonstrating their wares to buyers with the aid of strategically placed television receivers. Color would certainly make the presentation of dress materials, house furnishings, and the like more meaningful and appealing. Also, in the surveillance of inaccessible industrial operations by television, color transmission may aid the discrimination of the observer, marking out, for instance, danger signals requiring immediate action.

All systems of color television so far proposed, just as the familiar systems of color photography, are based on the observation that any color impression may be created by the superposition of three primary color stimuli—for example, red, green, and blue—in proper balance. The employment of suitable filters thus makes it possible to separate a natural-color image into three monochrome partial images which, on superposition, recreate, as far as the observer is concerned, the image in its original colors. The first efforts to adapt modern electronic techniques to color television employed the sequential transmission of three partial images in red, green, and blue, using the same pickup and viewing tube. In a relatively recent version (Fig. 8), the image of the scene is projected through a rotating filter disk onto the photocathode of an

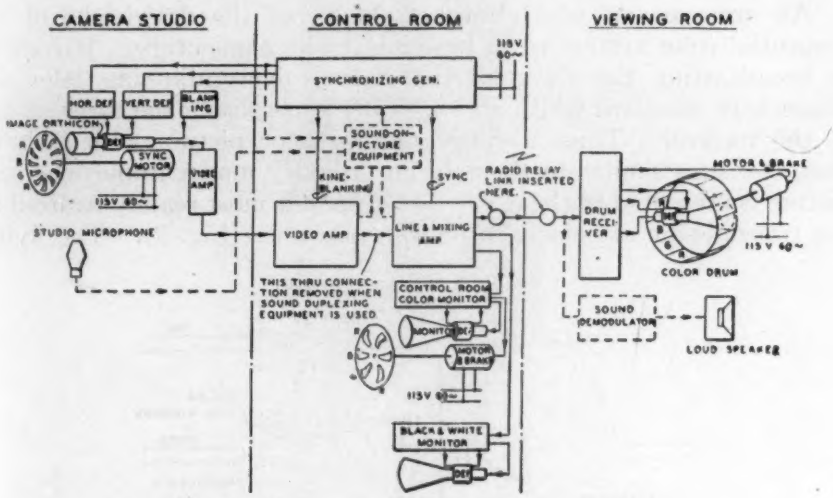

FIG. 8. Block diagram of sequential color television system.

image orthicon and the viewing tube observed through a filter drum synchronized with the filter disk of the pickup tube. Thus as the red content of the image, recorded on the mosaic of the image orthicon, is swept off by the scanning beam, it is presented to the eye of the observer by the kinescope through a red filter; a hundred-twentieth of a second later, the green content is similarly transmitted, and in the following hundred-twentieth, the blue content. Because of the persistence of vision the eye combines the three color contents so as to convey to the brain the impression of a single picture in natural colors. A complete picture (that is, six partial pictures, taking account of interlacing) is presented to the eye every twentieth of a second. The number of picture elements transmitted per second is just twice that for a monochrome transmission with a picture period of a thirtieth of a second, so

that the frequency band required for the transmission is also just twice as large.

Technically, both adequate color reproduction and adequate definition can be obtained in this manner. However, because of the large light losses due to the color filters, the picture brightness does not compare with present black-and-white television. The low picture rate is such as to cause the image to flicker objectionably, even at the lower brightness. Furthermore, color "break-up," that is, color flashes observed when the head is moved rapidly, proves at times to be annoying. Additional drawbacks are the large, rapidly moving color wheels or drums and the fact that there is no known way in which present black-and-white receivers may receive transmissions from such a color system.

An arrangement which removes many of the drawbacks of the sequential color system is, in principle, quite elementary. It consists in broadcasting the three partial images over adjoining television channels of standard width and optically superposing the three images at the receiver. Thus, a single natural-color picture with stability characteristics similar to those of an ordinary monochrome television picture is presented to the eye. The system is most readily realized for the transmission of color film or transparencies (Fig. 9). The flying-

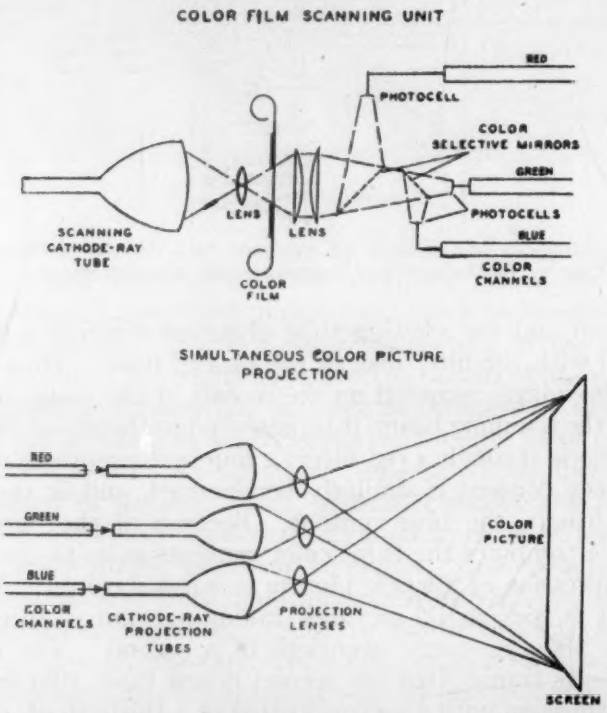

FIG. 9. Block diagram of simultaneous all-electronic color television system.

spot method, here employed, assures perfect picture registration—that is, the transmission of the identical picture element over the three channels at any instant—at the transmitter. The scanning pattern from a flying-spot tube with a white, low-persistence phosphor is imaged onto the color film transmitted and the aperture of the imaging lens, in turn, is imaged through the film and through a beam-splitting system on the cathodes of three multiplier phototubes: their output represents the picture signal for the red, green, and blue content of the color picture.

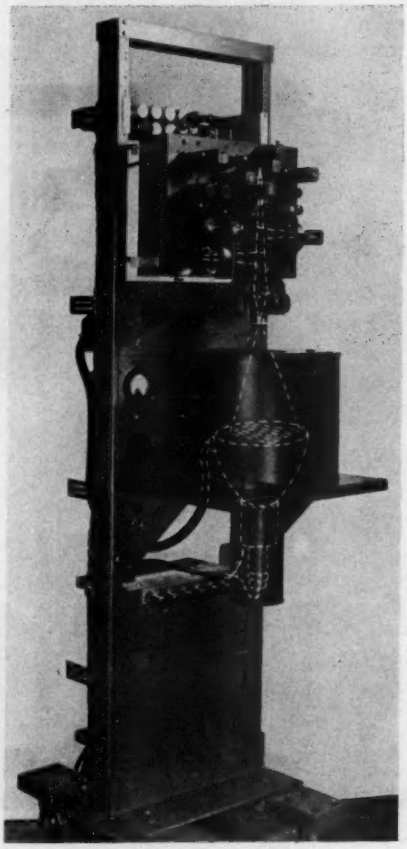

FIG. 10. Stationary picture signal generator.

The beam-splitting system consists of two dichroic plates inclined at 45 degrees to the optic axis: the first plate reflects the red and transmits the green and the blue, the second reflects the blue and transmits the green. Additional filters and the adjustment of the operating voltages of the multiplier phototubes make it possible to attain satisfactory color balance.

In the receiver the three signals are applied to the grids of three kinescopes with red, green and blue phosphors. The picture formed on

the kinescope faces are then projected by lenses displaced slightly with respect to the tube axes on a common screen. It is clear how, with this system, a monochrome receiver can respond to a color program—the signal from the green channel, which normally comes quite close to reproducing the brightness gradation in the complete color picture, is simply applied to the grid of the single kinescope to yield a black-and-white picture; on the other hand, the color receiver may reproduce a black-and-white picture from a monochrome transmitter by applying the identical picture signal to all three kinescopes.

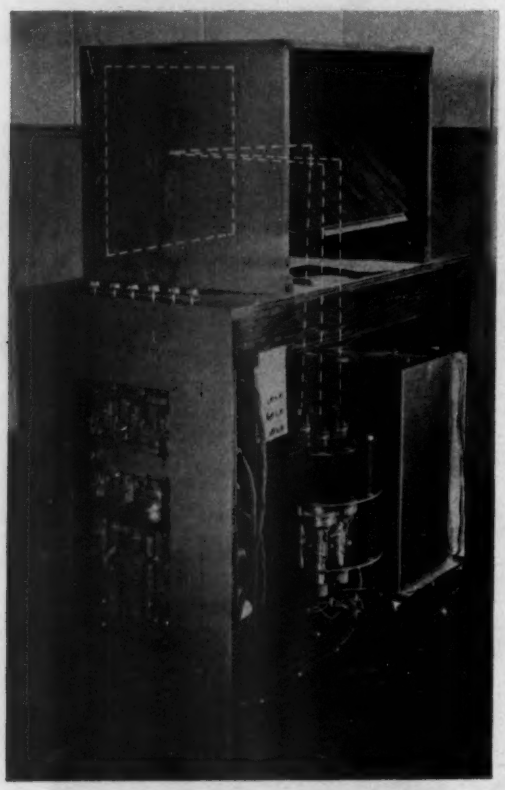

FIG. 11. Rear view of simultaneous color receiver, showing projection paths.

In the physical realization of the pickup system for still transparencies, the flying-spot tube is enclosed in a suitable shield and mounted on the rack carrying the auxiliary electrical equipment (Fig. 10). The principal ray paths are marked on the figure. A corresponding view of an experimental receiver (Fig. 11) shows the three kinescopes with their associated f/2 projection lenses arranged at the three corners of an equilateral triangle. The equipment to be demonstrated * deviates

* Television images of a series of color slides and films were projected, at the end of the lecture, on the screen. The picture size was 7-½ × 10 feet.

from this in employing reflective projection optics with aspheric correction plates for each kinescope (Fig. 12). This is necessitated, on the one hand, by the greater light requirements of the larger projected picture and rendered possible, on the other, by the greater distance between tubes and screen. The last reduces to a reasonable value the angular displacement of the center of the image on the screen with respect to the optic axes of the individual projection systems, even though the projection systems demand large separations between the tube axes. The physical arrangement of the components is evident from the photographs of the equipment (Figs. 13 and 14).

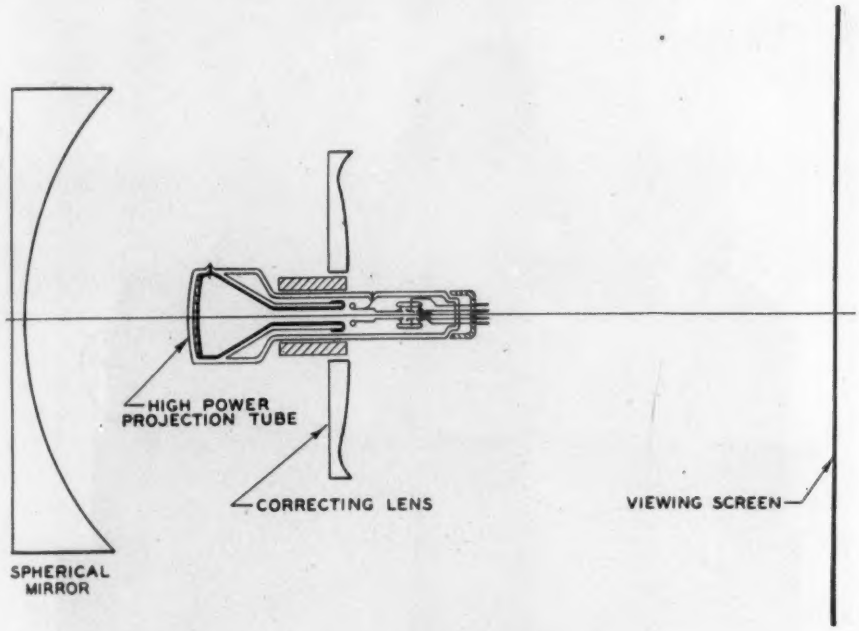

FIG. 12. Diagram of projection optics.

It may be pointed out that the employment of a reflecting backing for the fluorescent screens of the three kinescopes is, in this application, not only desirable to increase picture brightness and contrast, but also necessary to prevent poor registration resulting from image shifts produced by the charging up of the screen material. At the same time it will be noted that the registration is not as critical as might have been surmised: the fact that image detail is, in general, adequately conveyed by the green and red pictures alone, may make it permissible to reduce the total frequency band required for the transmission by employing a narrow frequency band, yielding relatively low definition, for the blue channel and reserving a broad, high-definition, band for the green and red channels. These, and many other practical questions, must be left

to the future. It is hoped that today's demonstration may give an idea of the status of simultaneous color television at the present, showing both its imperfections and its promise. With regard to future plans it will be RCA's objective in the field of black-and-white television to continue technical developments of equipment for the receiver, the transmitter and the studio so as to give to the public all possible improvement in this type of service. Work will be carried forward on additional radio relay chains to provide for more networking of television stations throughout the country, and work will continue on new types of programs to provide new interest for the viewing public.

FIG. 13. External view of demonstration equipment.

Color television is still in the laboratory stage and will continue to be for at least a few years to come. The objective of RCA in this field is to create an all-electronic color system equal in clarity to that of our present black-and-white all-electronic method. To this end developments will be continued on the equipment for the receiver, the transmitter and the studio in the direction of improving performance, simplifying the equipment and increasing its reliability and ease of operation. Field testing will proceed until sufficient data has been collected to form a basis for setting up standards for this service.

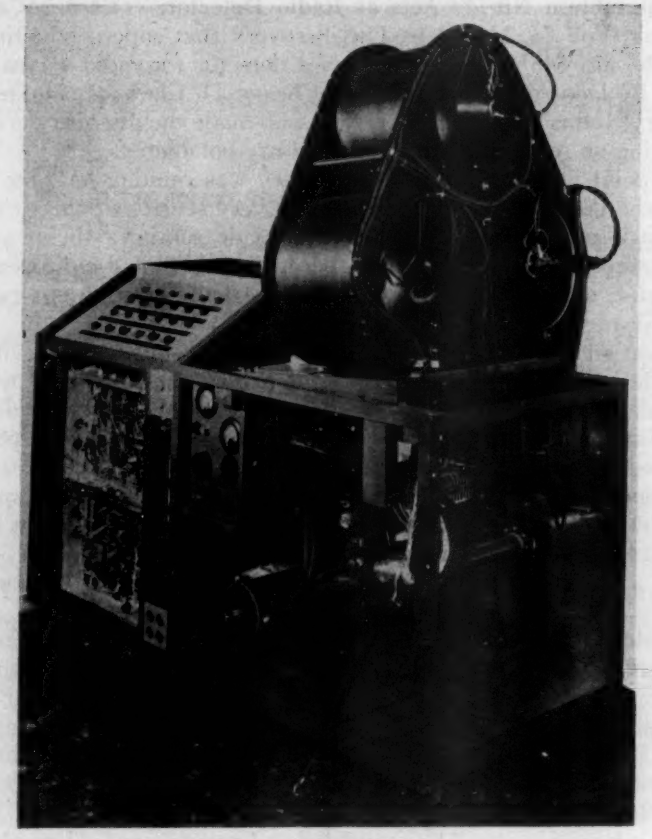

FIG. 14. View of demonstration equipment with shields removed.

ACKNOWLEDGMENTS.

The equipment which will be demonstrated is the product of the cooperative efforts of several research groups at RCA Laboratories in Princeton. The principles as presently used in this all-electronic simultaneous color television method are the products of R. D. Kell and his associates. The projection receiver was designed and built by D. W. Epstein's Cathode Ray and Optics Section. In addition to the general direction of the project D. W. Epstein contributed the optical design, while F. H. Nicoll provided the special projection kinescopes required. The completion of the apparatus was furthered materially by J. Ford in the Drafting Department and R. A. Marple in the Model Shop. The flying-spot color pickup was developed by R. D. Kell's Television Section, largely through the efforts of G. C. Sziklai, A. C. Schroeder, and K. R. Wendt.

Cold Columbium Nitride Acts as Radio Detector. (*Chemical and Engineering News*, Vol. 24, No. 24.)—The discovery that superconducting columbium nitride, at –345° F., will serve as a detector for radio waves has been announced by Donald H. Andrews and Chester D. Clark, of the Department of Chemistry, Johns Hopkins University, who made the discovery accidentally while carrying on research on the infra-red ray bolometer.

At one point in the work when a battery was running low, Dr. Andrews turned off the heating coil that governs the very sensitive point at which columbium nitride strip in the bolometer is made sensitive to infra-red rays. When the temperature fell to –345° F. because of the liquid hydrogen encasing the bolometer, a loudspeaker that is used in the system to observe audible effects began to issue a local broadcast program.

Investigation showed that through the medium of superconductivity, columbium nitride was functioning as a radio detector. Its discovery was due to the fact that it was connected to a standard audiofrequency amplifier.

Depending on superconductivity, this is an entirely new principle of radio reception and is a fundamental dicovery of great potential significance. Dr. Andrews reports that it is too early to forsee what directions its applications will take, but it seems apparent that it may influence trans-ocean and other long distance radio communication.

R. H. OPPERMANN.

Synchroton to Yield Aritificial Cosmic Ray Particles. (*Chemical and and Engineering News*, Vol. 24, No. 24.)—A 300,000,000-volt 15-ton synchroton with 28 miles of glass tubing, which will "produce energy similar to that of cosmic rays, permitting scientists to go a step beyond atom-smashing to study subnuclear particles," is being constructed. It will be built by University of Michigan physicists in association with the Applied Physics Laboratory of Johns Hopkins University under special research contracts with the Navy Bureau of Ordnance, and will be completed early next year. Through the miles of glass tubes, the electrons will whiz at a rate nearing the speed of light, 186,000 miles per second. At top speed, the negatively-charged particles will make 425,000 laps around, traveling 2320 miles in one-eightieth of a second. The electron path is made up of four quarter-circles connected by straight parts, and in this it differs from other synchrotons, in which the electron path is circular.

Many important experiments completely impracticable with cosmic rays are anticipated, because of the controllability and great intensity of the electron beam. In fact, the Michigan scientists say that though it is difficult to predict what the research results will be, the field to be investigated will be "relatively untouched, and worth getting into at any cost".

R. H. OPPERMANN.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

HIGH-TEMPERATURE HIGH-STRENGTH PORCELAINS.

New all-crystalline porcelains, having exceptional mechanical and dielectric strength at temperatures extending up to 2,000° F., have been developed in the Bureau's Porcelain and Pottery Laboratory. Such porcelains are particularly valuable for sustaining loads at elevated temperatures, as electrical insulators at elevated temperatures, and as insulators for such special applications as aviation spark plugs and radar transformers.

The composition of these new porcelains is characterized by the use of such materials as alumina, beryllia, zirconia, and thoria, with minor additions of other metallic oxides, and by the absence of silica. A representative high-beryllia porcelain contains 84 per cent. beryllia and 8 per cent. zirconia, with small amounts of lime and alumina; a typical high-zirconia composition is 80 per cent. zirconia, 10 per cent. beryllia, and 10 per cent. magnesia.

In 1940 the Bureau began a series of investigations to develop glass-free ceramic bodies of the porcelain type which would have simple compositions favorable to high mechanical strength, particularly at elevated temperatures, and good resistance to thermal shock, properties not found in the conventional porcelains. The usual porcelain composition includes feldspar, which reacts as a flux with clay and silica, dissolving them in part to produce a viscous liquid. The liquid fills the interstices between the crystalline phases of the mixture, and upon cooling, becomes a matrix of glass upon which the strength of the porcelain is largely dependent. This glass will soften and deform under stress at temperatures much lower than the temperatures at which the crystalline phases liquefy.

The work, initially undertaken as a fundamental contribution in the field of ceramics, was accelerated by the war-time demands for a material that would resist deformation at temperatures up to 2,000° F. for use in jet propulsion and gas turbine engines. A decided advantage of ceramic materials for this purpose, if other properties are satisfactory, is their low density as compared with the high-temperature metallic alloys. Accordingly, the investigation was extended under the sponsorship of the NACA to include strength and creep characteristics in pure tension at temperatures ranging from 1,500° to 2,000° F. On the basis of preliminary tests, six compositions were chosen for further

* Communicated by the Director.

study, and tension specimens were made commercially from specifications furnished by the Bureau.

Tensile tests require perfect alinement of the stressing members and freedom from bend of the specimen. Furthermore the supporting members must be of a material that will withstand the stresses and temperatures involved. Therefore adapters, through which stress may be applied to the specimens, were perfected. These adapters are porcelain cylinders (all of the adapters were made from the same experimental composition), threaded internally on one end to receive the tension specimens and externally on the opposite end. The assembly of tension specimen and two adapters is of such length that the outer ends of the adapters protrude from the furnace. The adapters, in turn, screw into brass heads which connect through universal joints to the loading device.

Creep or extension of the specimens under load is indicated by a gage similar in principle to those used at the Bureau for measuring creep of metals. Fabricated from platinum-rhodium alloy, it consists of a cut-away tube and a wire that moves freely in this tube. When cemented to the specimen in two places, relative movements of the specimen are determined by observing reference lines on the wire and on the cut-away section of the tube. By a special optical apparatus—an illuminated Gaertner extension-viewing device provided with a filar micrometer eyepiece—measurements of the creep may be observed with a precision of 1 micron, and readings interpolated to 0.1 micron. Two gages, 180° apart are used in each test.

In the early phases of the body development work, preceding the creep tests, a furnace was designed for the high temperatures required. Capable of accurate control at high temperatures, the furnaces are electrically heated with special oxide resistors that are stable in an oxidizing atmosphere. Furnaces have been built that have attained a temperature of 3,700° F. By means of a combination of manual and automatic temperature controls, an average air temperature may be maintained over the entire gage length to plus or minus 5° F.

Tests show that all of the compositions are very resistant to deformation or creep at temperatures up to 1,800° F. for long periods of time. A typical specimen, for example, showed an elongation of 0.23 per cent. after a total of 2,600 hours, during which the applied stresses ranged from 9,000 to 14,000 pounds per square inch. At temperatures of 1,900° F. and higher, however, the tendency to creep is more pronounced and appreciably lower stresses produce a creep rate measurable by the hour.

Research and development are continuing in the field of high-temperature porcelains, for ceramics offer definite promise of usefulness in the high-temperature regions where metallic alloys are no longer serviceable.

BETATRON RESEARCH IN MULTIMILLION VOLT RANGE.

Plans have been completed at the National Bureau of Standards for the erection of two betatrons, enabling Bureau scientists to extend research, measurements, and standards development into the 50 and 100 million volt range.

Two immediate problems calling for extensive investigation are the determination of measurement techniques and the formulation of precautionary principles in the use of the betatron for cancer treatment.

For the past twenty years, the National Bureau of Standards has played a central role in the development of standards for x-ray dosage measurement and protection. The field has been covered thus far only up to one and a half million volts. For this purpose, the Bureau now has one of the best equipped x-ray laboratories in the world. Because of its facilities and its experience in the field of radioactivity as well as x-rays, outside organizations such as the radiological and medical groups, the Manhattan District, and the International Commission on Radiation Protection and Radiation Dosage, are looking to the National Bureau of Standards for extension of x-ray measurement activities into the newly opened multimillion volt range.

The betatron is a device for producing electrons or x-rays of extremely high energies and frequencies. Both as an x-ray device and as an electron beam generator, the betatron has unusual potentialities in the fields of medical, biological, industrial, and nuclear research.

It consists essentially of a large alternating current magnet, in the center of which is an evacuated tube having a doughnut shape. Electrons are admitted into this tube, where they describe a circular orbit under the influence of a magnetic field, making hundreds of thousands of revolutions in a fraction of a second. When these energized electrons strike a target within the tube, extremely penetrating x-rays are produced. The tube may be arranged so as to emit electrons directly, and electron beams having a range of several feet may be produced in air.

As a medical tool, the betatron can provide x-rays suitable for cancer treatment under conditions long dreamed of but never realized. With 20 million volt radiation, it is possible to deliver to a sub-surface tumor all the radiation it can stand and yet not seriously jeopardize the skin. Recent research has indicated that the electron beam may also be used directly in therapy, for the beams have the property of passing through the surface and sub-surface tissue with negligible absorption. Yet at a controllable depth, all of the energy of the electron beam is given up and absorbed by a tumor.

During the war, the betatron came into limited industrial use for the inspection of heavy metal objects such as guns, shells, and large castings. Photographic exposures could be made through a foot or more of steel in a matter of seconds, using a betatron, whereas the older methods utilizing radium required hours.

The problems of protection in both the medical and industrial applications of high voltage radiation are immeasurably greater in the multimillion volt range than in the lower regions heretofore encountered. Heavy protective barriers and expensive overall installations are required, but the exact protection measurements and techniques are as yet unknown. One of the aims of the Bureau study is to discover the necessary thicknesses and types of construction that will give maximum protection with lowest overall costs. Industrial use, in particular, presents difficulties not encountered in the medical applications, and the establishment of safe working conditions for industrial betatron use is one of the principal objectives.

The betatron is also an important tool in nuclear or atomic research. Many nuclear transformations are brought about simply by exposing materials to the powerful x-ray beam. It is planned to make a systematic study of these transformations, which constitute a phase of atomic research virtually untouched at present.

Some of these transformation processes may take place when the human body is exposed to radiation, and it therefore becomes essential that they be thoroughly understood in connection with any biological or medical experiments. An understanding of these processes will also contribute materially to the general fund of atomic knowledge.

The 1946 Congress authorized and appropriated funds for the construction of a special building and the installation of a betatron at the Bureau.

The betatron was designed to operate up to 50 million volts, although the building was designed to house much larger equipment as it became available, equipment up to 150 million volts and probably higher. While the building designs have been completed by the Public Buildings Administration, the program has been retarded by the sharp increase in building costs since the appropriation estimates were made. The action of Congress is awaited before proceeding with the construction program.

The main chamber in which the betatron is to be housed, and the x-rays produced, will be completely buried underground and covered by several feet of concrete and earth. This is to prevent any direct radiation from escaping and harming nearby workers.

The sensitive measuring equipment will be housed in an adjoining smaller room. In combination with these two rooms, facilities have been designed for determining the protective values of concrete and other materials, under conditions that will permit of their broad interpretation in the medical and industrial x-ray field.

This latter point is of particular importance, since it is almost impossible to obtain this information with any of the existing or contemplated betatron installations. Requirements for this work are such that the buildings must be specially designed and constructed just for the purpose of determining protective values. The operators of the equip-

ment will be separated from the betatrons by a concrete labyrinth and a five foot thick concrete wall, operating all equipment by remote control devices.

The first betatron planned will operate up to 50 million volts. Although this is not the largest device available, it is essential to provide for the production of x-rays from the relatively low voltage of 1 million up to the higher 50 million volts. The region between 1 and 20 million volts is of extreme importance in medicine and biology. Large instruments, unfortunately, cannot operate successfully in this lower range.

The 1947 budget request calls for the addition of a 100 million volt betatron which will enable the Bureau to extend its studies above the 50 million volt limit of the smaller instrument. It is in this higher region that atomic and nuclear phenomena begin to become more evident.

Broad cooperative programs of research are planned with the National Cancer Institute and the Carnegie Institution of Washington. The National Cancer Institute has excellent facilities for biological investigations, while the Carnegie Institution has available both a cyclotron and a Van der Graff generator. Acquisition of betatron facilities by the National Bureau of Standards, in conjunction with its established radioactivity and x-ray laboratories, serves to round out the biological, medical, and biophysical radiation facilities of the Washington area in the high energy radiation range.

Powdered Coal Offers Automatic Home Heat. (*Coal Age*, Vol. 52, No. 1.)—Automatic home heating from powdered coal is developing as a byproduct of the gas turbine for railroad locomotives recently announced by the Locomotive Development Committee of Bituminous Coal Research, Inc., and is now coming out of the laboratory for testing as a business venture. If a commercial success, it opens a new vista for clean, simple and smokeless heating without bother to the householder, who would do no handling, shoveling nor ash removing. Waste gases would be vented off through an exhaust pipe or up the chimney. The "push-button" warmth would be regulated by the same thermostatic controls used for oil or gas burners.

This test of commercial practicability of powdered coal for automatic home heating is being undertaken by William B. Rogers of Baltimore, a coal wholesaler of many years' experience and at one time manager of the fuel-oil department of an oil refiner. He has formed a company which is erecting a central plant on a railroad siding for pulverizing bituminous slack in volume.

Initially, the automatic-heating units will be placed in small commercial establishments doing canning, bottling, dry cleaning, baking and such for serving steam boilers of 75 to 150 hp., using an aggregate of 6000 tons of coal a year.

Thereafter, Mr. Rogers proposes to sell the multi-family and individual home-heating business, as a merchant operating on an annual heating-service contract basis. Although his system is adaptable to existing furnaces, a special furnace of house-size capacity, a vertical sheet metal cylinder lined with refractory, is to be available. Top-mounting of the powdered-coal burner provides for vertical down-firing after ignition by a gas pilot and sparkplug. A screw conveyor at the bottom of the airtight hopper brings the fluffy black dust to the blower for carburetion into the air stream going into the burner. A small take-off line from the blower gusts secondary air into the flaming chamber for more complete combustion.

Calculated on the basis of a six-family apartment building in Baltimore, Md., the fuel cost of pulverized coal would approximate $315 a year, according to Mr. Rogers. This would be appreciably less than competitive gas and oil fuels. Mr. Rogers also claims that considerable savings would be effected over the hand-fired or stoker-fired coal burners. While installation cost of $500 for the heating unit looks high, no janitor is needed and the customer pays nothing directly for maintenance and depreciation. Savings on these should pay for the furnace installation in about three years, Mr. Rogers believes.

R. H. OPPERMANN.

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Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print 9 × 14 inches is thirty-five cents.

The Library and reading room are open on Mondays, Tuesdays, Wednesdays, and Fridays from 9 A.M. until 5 P.M., Thursdays from 2 P.M. until 10 P.M., and Saturdays from 9 A.M. until 12 noon.

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*This list should have been included in the Membership List published in the July, 1947, issue. It was necessary to omit it in that number.—ED.

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NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

The Blood Picture of Normal Laboratory Animals.[1] **A Review of the Literature, 1936–1946.**—MARY VIRGINIA GARDNER.

THE MONKEY.

Reports on the blood of both New World and Old World monkeys have been found in the literature. No direct comparisons should be made between the two, since they belong to distinct families of anthropoids. The New World monkeys used in the studies reviewed here belong to the genera Ateles, Cebus, Aotus and Leontocebus. The Old World monkeys used belong to the genera Cercocebus (the mangabey of Africa) and Macacus (the rhesus, or Macacus mulatta, of India).

TABLE I.

Erythrocytes.

Age of Monkeys	No. and Sex of Monkeys	Strain	Erythrocytes $\times 10^6$/cmm.		Diameter μ	Reported by
		Old World Monkeys	Average	Range		
6–24 months	8 M+F	M. mulatta	4.197	3.56–4.76		Suarez (3)
18–24 months	15 M+F	M. mulatta	6.38	5.09–7.33		Jones (4)
20–48 months	19 M+F	M. mulatta	5.2	3.6 –6.8		Shukers (5)
3–4 years	4 M+F	M. mulatta	5.173	4.49–6.05		Suarez (3)
adult	11	M. rhesus	6.20	4.72–7.66	7.04	Bussabarger (6)
adult	10	M. rhesus	4.81	3.95–6.09		Cooperman (7)
adult	2 F	M. rhesus		5.0 –6.0		Crafts (8)
adult	7 M	M. mulatta	4.82	4.3 –6.0		Day (9)
adult	4 F	M. mulatta	4.86	4.5 –5.2		Day (9)
adult	2 M	M. mulatta	5.28	5.21–5.35		Day (10)
adult	19	M. mulatta	5.2	4.6 –5.8		Langston (11)
adult	59	M. rhesus	5.76	4.23–7.61		Majunder (12)
adult	4	M. rhesus	5.68	4.8 –6.8		Scott (13)
adult	5	M. mulatta		4.17–6.07		Smith (14)
adult	26 M+F	M. mulatta	5.233	3.55–6.86		Suarez (3)
adult	4	M. mulatta	5.32			Tyslowitz (15)
adult	3	M. rhesus	4.94	4.54–5.38		Verder (16)
Average			5.281			
adult	4	Cercocebus		4.00–5.16		Smith (14)
		New World Monkeys				
adult	5	Ateles		4.0 –6.25	7.6	Taliaferro (17)
adult	13	Cebus		4.0 –7.0	7.1	Taliaferro (17)
adult	3	Aotus		4.0 –5.0	6.6	Taliaferro (17)
adult	2	Leontocebus		3.0 –5.5	7.5	Taliaferro (17)

[1] Continued from page 502, Vol. 243, No. 6.

Method of Obtaining Blood.—Blood is usually obtained by puncture of one of the larger superficial veins such as the saphenous or the femoral. A lancet stab into the deltoid muscle of the arm was found by Guthkelch and Zuckerman (1) to supply sufficient blood for routine hematological examination.

Red Blood Cells.—The erythrocytes of the monkey, like those of man, are non-nucleated biconcave discs. Little variation in the size of the erythrocytes of any one genus of Panamanian monkey was found by Taliaferro and Klüver (2). A distinct difference in mean diameter among genera was found by them, the average erythrocyte in the genera Cebus and Aotus being markedly smaller than that of the other genera studied and that of man (Table I).

Considerable fluctuation in the number of erythrocytes throughout the menstrual cycle of Macaques was found by Guthkelch and Zuckerman (1). The red blood cell count was lowest at the beginning and the end and highest in the middle of the menstrual cycle; the maximum variation amounted to 1,600,000 cells per cmm.

Howell-Jolly bodies were frequently found by Taliaferro and Klüver (2) in Cebus (1 in 600 cells) and occasionally in Aotus and Leontocebus. The bodies were uniform in size and no more than 1 per cell was found in the blood of normal animals. Normoblasts or immature red blood cells were only occasionally seen by them in the blood of normal monkeys.

TABLE II.
Reticulocytes.

Age of Monkeys	No. and Sex of Monkeys	Strain	Reticulocytes		Reported by
		Old World Monkeys	Per Cent. of Erythrocytes		
			Average	Range	
6–24 months	8 M+F	M. mulatta	2.9	1.4 –6.8	Suarez (3)
20–48 months	19 M+F	M. mulatta	0.6	0.0 –2.0	Shukers (5)
3–4 years	4 M+F	M. mulatta	1.85	1.4 –2.4	Suarez (3)
adult	4 M	M. rhesus	1.03		Harne (18)
adult	6 F	M. rhesus	1.13		Harne (18)
adult	19	M. mulatta	0.6	0.56–0.64	Langston (11)
adult	59	M. rhesus	1.19	0.0 –4.0	Majunder (12)
adult	26 M+F	M. mulatta	1.58	0.6 –2.6	Suarez (3)
adult	4	M. mulatta	0.7		Tyslowitz (15)
Average			1.04		
adult	4	Cercocebus		0.5 –1.5	Smith (14)
		New World Monkeys			
adult	5	Ateles		0.3 –2.0	Taliaferro (17)
adult	13	Cebus		0.05–2.2	Taliaferro (17)
adult	3	Aotus		1.8 –5.8	Taliaferro (17)
adult	2	Leontocebus		1.8 –6.0	Taliaferro (17)

TABLE III.

Hemoglobin.

Age of Monkeys	No. and Sex of Monkeys	Strain	Hemoglobin g./100 cc.		Method	Reported by
		Old World Monkeys	Average	Range		
6–24 months	8 M+F	M. mulatta	12.2	11.0 –13.6	Sahli-Hellige	Suarez (3)
18–24 months	15 M+F	M. mulatta	12.95	11.21–14.55	Evelyn	Jones (4)
20–48 months	19 M+F	M. mulatta	12.2		Newcomer	Shukers (5)
3–4 years	4 M+F	M. mulatta	13.1	11.6 –15.9	Sahli-Hellige	Suarez (3)
adult	11	M. rhesus	12.86	9.00–17.27	Newcomer	Bussabarger (6)
adult	10	M. rhesus	13.49	12.9 –14.28	Evelyn	Cooperman (7)
adult	7 M	M. mulatta	10.47	9.2 –12.5	—	Day (9)
adult	4 F	M. mulatta	11.12	10.0 –12.0	—	Day (9)
adult	2 M	M. mulatta	11.37	11.15–11.6	—	Day (10)
adult	19	M. mulatta	12.2	10.9 –13.5	—	Langston (11)
adult	59	M. rhesus	13.59	11.0 –16.78	—	Majunder (12)
adult	26 M+F	M. mulatta	13.2	11.0 –17.1	Sahli-Hellige	Suarez (3)
adult	4	M. mulatta	12.2		Newcomer	Tyslowitz (15)
Average			13.39			

The values reported in the literature for different strains of monkey are shown in Table I.

The reported values for reticulocyte number for different strains of monkey are shown in Table II.

Hemoglobin.—The reported values for hemoblogin concentration in the blood of Macaques are shown in Table III. No reports were found for the hemoblogin content of the blood of New World monkeys.

White Blood Cells.—The morphology of the May-Grünwald-stained leukocytes of normal and malaria-infected Panamanian monkeys has been described by Taliaferro and Klüver (2). All of the leukocytes, with the possible exception of the basophil, were found by them to be smaller than the corresponding cells in man. The lymphocytes were described by them as ranging in size from cells smaller than the heterophil to cells nearly as large as the monocyte. The lymphocyte was found to possess a round or slightly indented mucleus which contained dense, large masses of chromatin that stained purplish red to dark red and cytoplasm which stained blue and frequently contained distinct azurophil granules.

The monocyte was described by them as large (11–18μ) with voluminous cytoplasm containing varying numbers of spherical azurophil granules. The nucleus of the monocyte, they found, "was often indented, assumed a variety of shapes, and contained loosely arranged small masses of chromatin which stained less intensely than those of the lymphocyte."

The heterophil (neutrophil) was found to have a nucleus constricted into lobes which contained large dark red chromatin masses. Red

TABLE IV.

Leukocytes.

Age of Monkeys	No. and Sex of Monkeys	Strain	Leukocytes per cmm.		Cells per 100 Leukocytes					Reported by
		Old World Monkeys	Average	Range	Neut.	Eo.	Baso.	Lymph.	Mono.	
6–24 months	8 M+F	M. mulatta	15,107	10,050–21,750	36.88	3.06	0.44	57.76	0.18	Suarez (3)
18–24 months	15 M+F	M. mulatta	16,900	10,900–26,400	49.5	2.2	0.1	45.3	2.5	Jones (4)
20–48 months	19 M+F	M. mulatta	15,100	5,600–34,700	36.0	0.5	0.5	59.0	3.0	Shukers (5)
3–4 years	4 M+F	M. mulatta	17,562	14,550–22,500	38.5	4.0	0.0	56.74	0.75	Suarez (3)
adult	10	M. rhesus	13,090	10,000–15,600						Cooperman (7)
adult	2 F	M. rhesus		10,000–15,000						Crafts (8)
adult	7 M	M. mulatta	16,700	10,100–25,000	46.9			46.5		Day (9)
adult	4 F	M. mulatta	14,100	12,500–16,000	35.8			60.1		Day (9)
adult	2 M	M. mulatta	13,300	9,600–17,000	36.5			55.4		Day (10)
adult	19	M. mulatta	15,000	9,700–20,500	37.7			58.2		Langston (11)
adult	59	M. rhesus	15,380	6,300–28,000	48.3	2.2		47.9	1.61	Majunder (12)
adult	4	M. rhesus	19,000	11,000–32,000	43.9			56.0		Scott (13)
adult	25 M+F	M. mulatta	9,999	5,000–15,750	51.38	4.92	0.0	42.19	1.19	Suarez (3)
adult	4	M. mulatta	14,400		52.5	1.0	0.5	43.0	3.0	Tyslowitz (15)
adult	3	M. rhesus	14,575	11,000–17,900	38.2	1.0	0.0	59.36	0.83	Verder (16)
Average			15,554		43.46	2.26		52.07	1.66	
adult	4	Cercocebus		5,100– 5,800	12–35			62–84	3–4	Smith (14)
		New World Monkeys								
adult	6	Ateles		5,000–22,000						Taliaferro (17)
adult	14	Cebus		9,000–27,000						Taliaferro (17)
adult	3	Aotus		9,000–17,000						Taliaferro (17)
adult	2	Leontocebus		8,000–20,000						Taliaferro (17)

granules were found to be distributed more or less evenly throughout the clear unstained cytoplasm.

The granules of the eosinophils were at least twice the diameter of the heterophil granules and stained a tannish pink. The mean number of nuclear lobes in both heterophil and eosinophil was found to be higher in all species of monkey studied than in man.

The basophil was found to contain numerous round or slightly rod-shaped granules which stained a dark purple and practically obscured the rest of the cell.

The average of the values reported for the different types of leukocytes per 100 white blood cells in Macaques (Table IV) is:

Heterophils	43.46	(35.8–52.5)
Eosinophils	2.26	(1.0—4.9)
Basophils	rare	(0.0—0.5)
Lymphocytes	52.07	(42.2–60.1)
Monocytes	1.66	(0.8—3.0)

The average of the reported values for the number of leukocytes per c.mm. of blood in Macaques is 15,550.

In spite of acclimatization to the laboratory, Panamanian monkeys were found by Taliaferro and Klüver (17) to exhibit a leukocytosis which was probably due to the frequent handling incident to the procuring of blood samples. The normal total leukocyte count was found by them to vary from day to day and from hour to hour within a wide range because of changes in the heterophil count, in the lymphocyte count, or in both. Rhesus monkeys maintained on a natural diet (fruits, vegetables, cereals and bread) were found by Jones, McCall, Elvehjem and Clark (4) to have 15 per cent. fewer leukocytes per cmm. of blood and higher relative and absolute heterophil counts than those maintained on purified rations supplemented with whole liver and vitamins. No significant difference between the sexes was found in the number of any of the blood elements of normal rhesus monkeys by Shukers, Langston and Day (5).

Platelets.—The number of platelets per cmm. of blood in 10 young rhesus monkeys was found by Shukers, Langston and Day (5) to average 475,000 with a range of 203,000 to 935,000. The same average platelet count for 19 normal rhesus monkeys, with a range of 318,000 to 632,000, was given by Langston, Darby, Shukers and Day (11). The platelet count of 4 normal rhesus monkeys was found by Tyslowitz and Hartman (15) to average 332,000 per cmm. The number of platelets in the blood of infant Macaques was found by Suarez, Diaz Rivera and Hernandez Morales (3) to average 311,857 per cmm.; the number in the blood of young monkeys was found to average 377,750, and in the blood of adults, 306,880.

Hematocrit.—The average of the reported values (Table V) for the volume of packed red cells in the rhesus monkey is 42.5 per cent.

TABLE V.

Hematocrit.

Age of Monkeys	No. and Sex of Monkeys	Strain	Hematocrit per cent.		Reported by
		Old World Monkeys	Average	Range	
adult	11	M. rhesus	47.64	39.0–55.75	Bussabarger (6)
adult	19	M. mulatta	40.0	36.4–43.6	Langston (11)
adult	59	M. rhesus	44.98	38.0–53.3	Majunder (12)
adult	19 M+F	M. mulatta	40.0	31.8–49.0	Shukers (5)
adult	5	M. mulatta		35.0–45.0	Smith (14)
adult	4	M. mulatta	39.9		Tyslowitz (15)
Average			42.50		
adult	8	Cercocebus		34.0–50.0	Smith (14)

Clotting Time.—The clotting time of the blood of 10 young rhesus monkeys was found by Shukers, Langston and Day (5) to average 78 seconds and to range from 19 to 239 seconds.

No values for sedimentation rate, specific gravity, or resistance of red blood cells were found.

The values found for red blood cell count, hemoglobin concentration and relative numbers of neutrophils, lymphocytes and basophils agree with those recorded by Scarborough (19). The average number of reticulocytes and platelets and the average relative monocyte count were found to be somewhat higher, and the total leukocyte count and relative eosinophil count somewhat lower, than those given by Scarborough.

(*To be continued*)

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BOOK REVIEWS.

SECOND SYMPOSIUM ON THE STRUCTURE AND PROPERTIES OF DIAMOND. Reprinted from *Proceedings of the Indian Academy of Sciences*. 197 pages, illustrations, 18 × 24 cms. Bangalore, The Indian Academy of Sciences. 1946.

This second symposium contains a record of the progress in knowledge of this subject carried on since the first symposium in 1944. There are 21 papers divulging a wealth of interesting information including data on the thermal expansion, crystal symmetry of diamond and its x-ray reflections, luminescence of diamond excited by x-radiation, cleavage properties, theory of crystal forms of diamond, absorption of infra-red, ultra-violet, and spectrum of diamond, and phosphorescence and thermoluminescence of diamond. The papers are complete with curves, illustrations, and tables, all of which are reprinted from the *Proceedings of The Indian Academy of Sciences*.

R. H. OPPERMANN.

PIEZOELECTRICITY: An Introduction to the Theory and Applications of Electromechanical Phenomena in Crystals, by Walter Guyton Cady. 806 pages, drawings, 15 × 23 cms. New York, McGraw-Hill Book Company, Inc., 1946.

Piezoelectricity is defined as electric polarization produced by mechanical strain in crystals belonging to certain classes, the polarization being proportional to the strain and changing sign with it. Its discovery created considerable interest but for a third of a century it remained a scientific curiosity, unmentioned in many text-books, and furnishing material for a few doctoral theses. The exigency of the first World War led to experiments on properties and practical applications of piezoelectric crystals. These investigations have borne fruit in many useful peacetime devices. And today the subject has broad scope and research is being directed to further its theories. This has brought forth a need for a comprehensive treatise. The book at hand is one attempt to satisfy this need.

The boundaries of this subject extend irregularly to all branches of physics, particularly so into the realm of crystal physics so that definite borders must be drawn in order to have a comprehensive text. An examination of this book reveals that this was recognized and care was taken to focus the coverage on the most important, so that many topics such as thermal properties and plasticity if treated at all are treated only insofar as they have a bearing on the central theme. There are thirty-one chapters to the book which give the presentation in logical order. It opens with a chapter on crystallography giving only those principles needed for later understanding. This leads to the topics of crystal elasticity, rotated axes and transformation of elastic constants, and vibrations of crystals. Then there is given the results of observations of fundamental elastic constants of those piezoelectric crystals for which data are available including Rochelle Salt. Rochelle Salt and other Seignette-electrics are treated at some length covering the present knowledge of their properties and the accompanying theory. This fits in well with what is needed for an intelligent application of these crystals in technical devices.

Considerable space is devoted to the Piezo Resonator referring to the theory of those resonators consisting of bars in lengthwise vibration and plates in thickness vibration including a discussion of the manner in which the dielectric constants of a piezoelectric crystal vary with frequency and an account of the effect of piezoelectric vibrations on x-ray reflections. Further properties of the resonator including those of crystals vibrating in other modes are considered later as well as the application of the theory to particular crystals with some experimental results. Original material not found elsewhere may be found here.

There is shown how the new formulation of piezoelectric theory known as the "polarization theory" and other formulations may be derived from thermodynamic principles.

The book is a clear presentation of the subject valuable to research workers and others whose interests lie in this direction.

R. H. OPPERMANN.

A TEXTBOOK OF QUALITATIVE ANALYSIS, by William B. Meldrum and Albert F. Daggett. 431 pages, drawings, 14 × 22 cms. New York, American Book Company, 1946. Price $3.50.

This is a text on the general principles applicable to the study of qualitative analysis beginning with the structure of atoms and molecules and proceeding through an elementary coverage of reaction kinetics and the principle of Le Chatelier for the development of such expressions as those for the ionization constant for a weak electrolyte, the ion product constant of water, the pH of solutions, and the solubility product constant for slightly soluble electrolytes. With the application of the ionic theory, ionic reactions are classed into four categories in accordance with the types of compounds produced and with the electronic effects involved in the change. The subject of electrochemistry is briefly developed emphasizing upon the remarkable reactions that exist between the chemical and electrolytic properties of substances in acqueous solution, i.e., the interdependence of chemistry and electricity. Finally, adsorption and colloid formation, the two sources of error which may be particularly serious in analytical work are discussed.

What may be classed as the second part of the book is devoted to laboratory work. Here the semimicro method of analysis is used, first giving a set of preliminary experiments designed to familiarze the student with those reactions which serve to characterize and identify the cations and anions.

The representation is logical and clear, entirely within the grasp of first and second year students of college chemistry. Problems and exercises with answers are given at the ends of chapters. Also a reading list is appended and there is a subject index in the back.

R. H. OPPERMANN.

PHYSICAL CHEMISTRY, by Herschel Hung. 610 pages, drawings and tables, 14 × 22 cms. New York, Thomas Y. Crowell Co., 1947. Price $4.75.

Every student of science soon learns that when there are no means of making measurements on a process, resort must be made to mathematical calculations. And as he progresses it becomes increasingly evident that science and mathematics need to be tied closely together in order to obtain a thorough understanding. The author of this book has felt that there is need for a text on physical chemistry that combines sufficient emphasis on the mathematical formulation of ideas, fully explained step by step, with many illustrations and tables of data to clarify the discussions of fundamental principles and facilitate their interpretation. This book attempts to satisfy this need.

The work opens with a treatment on gases and leads into thermochemistry and elementary thermodynamics which is used as a foundation of later discussions. Derivation of many principles from experimental data are made and the general pattern is followed in treating on liquids. The subject of solids is next covered followed by solutions. There is a chapter on atomic structure and molecular properties giving facts and theories that are as much a part of physics as of chemistry. This section covering atom splitting and transmutation is indeed very interesting. Subsequent topics in order include the phase rule, chemical kinetics, photochemistry, homogeneous and heterogeneous equilibrium, ionic equilibrium, electrical conductivity and electrical transference, electrochemistry, statistical and quantum mechanics, and finally the colloidal state. There is a subject index in the back.

The method of presentation is clear and concise and in a logical order. Each equation as it comes up for use is completely developed, and their uses are illustrated by worked through solutions of problems. Problem exercises are numerous at the ends of chapters and they refer to principles covered to a great extent. Answers to these problems are found in the back of the book. The work deserves to be examined by teachers of the subject. Practicing engineers, chemists, and physicists will find it helpful as a refresher in unfamiliar fields and as a reference.

R. H. OPPERMANN.

PORTRAITS OF EMINENT MATHEMATICIANS, with biographical sketches by David Eugene Smith. Portfolio of 12 portraits. 25 × 35 cms. New York, Scripta Mathematica, 1946. Price $5.00.

This collection of portraits of eminent mathematicians is well suited for either classroom or home use, and the plates are particularly adapted for framing. The men included are Archimedes, Copernicus, Viete, Galileo, Napier, Descartes, Newton, Leibniz, Lagrange, Gauss, Lobachevsky, and Sylvester. Each reproduction has been taken from a life portrait and may be considered a faithful delineation of the subject. A short biographical sketch with other illustrative material accompanies each portrait. Originally issued in 1936, the portfolio may be judged by the necessity for this reprinting.

G. E. PETTENGILL.

SPEEDLIGHTS, CONSTRUCTION AND USE, by Arthur Palme. 128 pages, illustrations, 14 × 20 cms. Boston, American Photographic Publishing Co., 1946. Price $2.50.

This little volume presents a very comprehensive presentation of one of the latest developments in high speed photography—the speedlight. It had its beginnings in 1851 when William H. F. Talbot took out an English patent covering the use of an electric spark for instantaneous photography. In 1892 experiments by Professor Mach and C. V. Boys produced successful pictures of bullets in flight but little more was done until Prof. Harold E. Edgerton made public his modernized electric flash equipment in 1928. Following this brief historical outline the author gives descriptions of a typical speedlight and present day commercial equipment.

Practical considerations regarding the use of the speedlight are then discussed. The problem of securing synchronization between flash and camera is treated in detail and several methods are suggested for obtaining this under varying conditions. A comparison is presented between the photoflash and the speedlight with data on flash duration. Mr. Palme then presents three features of the speedlight which he feels will make it a popular illuminant with photographers:—elimination of changing bulbs after each exposure as with a photoflash; use instead of photofloods to avoid great heat radiation with accompanying saving in current consumption; and advantages in portraiture. The use of photocells in arranging multiple speedlights; the taking of pictures of sound waves, the x-ray ultra-highspeed radiograph and the illumination of large areas from planes are among other topics included.

For the home craftsman who wishes to make his own speedlight, a full description of the equipment and various steps necessary to make a simplified speedlight have been given. As the author points out, a speedlight is not cheap as the parts alone cost about $66.00. The final chapter carries a pertinent warning on the dangers of high voltage, a bibliography for further study and numerous examples of striking speedlight photographs complete a well-rounded survey of this new kind of photographic equipment.

G. E. PETTENGILL.

PUBLICATIONS RECEIVED.

Tables of Integrals and Other Mathematical Data, by Herbert Bristol Dwight. Revised edition. 250 pages, tables, 14 × 21 cms. New York, The Macmillan Co., 1947. Price $2.50.

The Strange Story of the Quantum, by Banesh Hoffmann. 239 pages, drawings, 14 × 21 cms. New York, Harper & Brothers, 1947. Price $3.00.

Inventions, Patents and Monopoly, by Peter Meinhardt. 352 pages, 14 × 22 cms. London, Stevens & Sons, Limited, 1946. Price 25 shillings.

Petroleum Production, by Park J. Jones. Vol. III. 271 pages, 16 × 24 cms., tables and drawings. New York, Reinhold Publishing Corporation, 1947. Price $5.00.

Guide to the Literature of Mathematics and Physics, Including Related Works on Engineering Science, by Nathan Grier Parke III. First Edition. 205 pages, 16 × 23 cms. New York and London: McGraw-Hill Book Company, Inc., 1947. Price $5.00.

Sequential Analysis, by Abraham Wald. 212 pages, tables, 15 × 24 cms. New York: John Wiley & Sons, Inc., London: Chapman & Hall, Ltd., 1947. Price $4.00.

CURRENT TOPICS.

New Ways of Producing Man Made Snow.—Approximately a dozen foreign materials have been found capable of nucleating cold-chamber snowstorms in a laboratory, it was announced in a paper presented at the annual meeting of the American Physical Society in New York City. The announcement was made by Dr. Irving Langmuir, associate director, Vincent J. Schaefer, and Dr. Bernard Vonnegut, all of the General Electric Research Laboratory at Schenectady. Best of the materials is silver iodide, they said.

Pointing out that a temperature of minus 31 degrees Fahrenheit is required for natural ice nuclei to form spontaneously, and that natural snowstorms often occur at temperatures higher than this, Dr. Langmuir said there is every reason to believe that nature often starts snowstorms with artificial nuclei. "And it is possible that one type of these artificial nuclei which Mother Nature uses may be some form of silver particles in supercooled clouds," he said.

Among other foreign materials capable of acting as artificial nuclei for producing snow are lead iodide, iodoform, iodine crystals, apatite, nephelite, wurtzite, zincite, and cerium oxide, the scientists reported.

In the new means devised for producing man-made snow, supercooled water droplets in a cloud are literally "fooled" into crystallizing on foreign nuclei rather than on natural ice nuclei, the G.-E. scientists related. Since each of the foreign nuclei has a crystal structure similar to that of ice, the droplets are "deceived" by the similarity and change to snow by using the foreign nuclei to initiate growth.

Since most of the foreign or artificial nuclei become active at temperatures much higher than the temperature necessary for ice nuclei to form spontaneously, their discovery considerably enhances man's ability to "make it snow," according to the scientists.

Although at too early a stage for prediction of actual uses, the discovery might make possible the seeding of vast areas of atmosphere with foreign nuclei. Unlike ice nuclei, which melt or evaporate, many such artificial nuclei might be introduced by generators on the ground into the atmosphere and remain there until they produce snow, the scientists said.

Dr. Langmuir pointed out that atmospheric seeding with artificial nuclei might eliminate severe airplane icing conditions over large areas and might curtail to great extent severe hailstorm activity prevalent in parts of the midwest.

"Undoubtedly, some climatic or weather changes would ensue from vast area seeding, but we are in too early a stage to speculate on that," Dr. Langmuir said.

An indication of how small an amount of silver or other critical material would be necessary for artificial seeding was given by Schaefer, when he estimated the size of nuclei to be of the order of 100 Angstroms, or about one millionth of an inch in diameter. "On this basis, if everyone in the United States were given 10,000 such nuclei, the total would be the equivalent of about one grain of salt," he calculated.

Dr. Langmuir estimated that approximately 200 pounds of silver iodide might prove sufficient to seed the entire atmosphere of the United States at a rate of 100,000 nuclei per cubic foot. "About one pound of silver iodide per hour of additional seeding probably would be required to maintain this condition," he added.

In experiments with silver iodide described by Dr. Vonnegut, a silver iodide-coated string was fed into a high-temperature flame, changing the silver iodide to a gas. Simultaneously a jet of air, blown over the flame, cooled and diluted the gas, causing formation of an invisible "smoke" of extremely-small silver-iodide particles in crystalline form. This "smoke" was then collected in a rubber bulb and kept there until ready for use.

When the silver-iodide, in this form, was dispensed into a supercooled cloud in a cold chamber, water droplets comprising the cloud crystallized on the silver-iodide nuclei, and snow resulted.

The transformation from water to snow took place at a temperature of plus 15 degrees Fahrenheit, as contrasted to minus 31 degrees necessary for spontaneous ice nuclei.

Lead iodide, in similar experimentation, accomplished transformation from water to snow at a temperature of zero Fahrenheit.

Schaefer's original snow-making technique, in which he caused spontaneous growth of natural ice nuclei by introducing dry-ice, initiates crystallization or change from water to snow at any temperature below 32 degrees Fahrenheit.

Most novel experiment was conducted by Robert Smith-Johannsen, another laboratory member, when he discovered a use for the "cigarette lighter that doesn't work." Flicking a cigarette lighter, which contained no fluid, he noticed smoke given off from the spark and hit upon the idea that particles contained in the smoke might serve as nuclei.

He sparked the lighter in a supercooled cloud, and snow formed. Particles from the flint proved to be the nucleating agents, and the "flint" upon analysis proved to be commercial ceruim. Thus, cerium oxide became listed as a possible type of nuclei for snow.

At present, methods are being developed by the G.-E. Research Laboratory to carry on outdoor experiments in natural conditions. The work will be undertaken in conjunction with the U. S. Army Signal Corps Engineering Laboratories, Bradley Beach, N. J., and the U. S. Army and Navy Air Forces.

R. H. O.